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Visual Attention to Social and Non-Social Objects in the Autism Spectrum

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Abstract

Autism Spectrum Disorders (ASDs) are characterised by impairments in social interaction and communication, and restricted interests or repetitive behaviours. Autism traits are theorised to lie on a continuum throughout the general population, with individuals with a clinical diagnosis at one extreme. Those with high levels of autism traits in the general population have been found to display similar characteristics to those with ASD, but to a lesser extent. Differences in visual attention to social and non-social information are thought to contribute to the characteristic behaviours in autism. Whilst social attention may be diminished in ASD, ASD may also be associated with an increase in attention towards objects that are of circumscribed interest. The present thesis investigated visual attention to social and non-social objects in participants with ASD and those from the general population with high and low autism traits, to investigate whether differences in social and non-social visual attention relate to the autism spectrum. Dot probe, peripheral cueing, and eye tracking tasks were used to explore different elements of visual attention, including orienting and disengaging. Overall, social objects captured attention more than non-social objects, revealing the high salience of social information. Participants with high levels of autism traits and a diagnosis of ASD showed reduced social attention in the dot probe and eye tracking tasks, but not the peripheral cueing experiment. Across all experiments, there was no evidence to suggest that the autism spectrum was related to attentional biases towards objects related to circumscribed interests. However, other non-social stimuli appeared to capture attention to a greater extent across the spectrum. The differences in social attention in those with higher autism traits and ASD appeared greater when more stimuli were competing for attention, suggesting reduced social attention may involve interference from non-social stimuli in the visual field. This may indicate that attention is guided more by visual properties of the stimuli than their semantic meaning in the autism spectrum.

List of Abbreviations

ADI	Autism Diagnostic Interview
ADOS	Autism Diagnostic Observation Schedule
AOI	Area Of Interest
AQ	Autism Spectrum Quotient
AS	Asperger's Syndrome
ASD	Autism Spectrum Disorder
BAP	Broad Autism Phenotype
BAPQ	Broad Autism Phenotype Questionnaire
CI	Circumscribed Interest
EMB	Extreme Male Brain (theory of autism)
EPF	Enhanced Perceptual Functioning
ERP	Event Related Potential
FFA	Fusiform Face Area
HFA	High Functioning Autism
fMRI	Functional Magnetic Resonance Imaging
IoR	Inhibition of Return
HSF	High Spatial Frequency
ISI	Inter Stimulus Interval
LSAS	Leibowitz Social Anxiety Sale, Self-Report
LSF	Low Spatial Frequency
MEG	Magnetoencephalography
OCD	Obsessive Compulsive Disorder
PDD-NOS	Pervasive Developmental Disorder Not Otherwise Specified
RRBI	Restricted and Repetitive Behaviours and Interests
RT	Reaction Time
SAD	Social Anxiety Disorder
SATQ	Subthreshold Autism Traits Questionnaire
SOA	Stimulus Onset Asynchrony
SRS	Social Responsiveness Scale
SRS2-AS	Social Responsiveness Scale, Adult Self Report Version
ToM	Theory of Mind
WCC	Weak Central Coherence

Chapter 1
Background

Chapter Abstract: Chapter 1 identifies the diagnostic features of Autism Spectrum Disorder (ASD) and highlights some of the difficulties faced by individuals with a diagnosis, particularly in relation to the social world. The concept of a subclinical spectrum of autism traits is illustrated and theories of ASD are considered, with emphasis on cognitive explanations in which the present thesis is grounded.

1.1 Autism Spectrum Disorders

1.1.1 *Definition and Diagnostic Terms*

In its earliest description, children with autism were described as behaving as though other people were not present, and interacting with parts of them, such as hands, as though they were objects (Kanner, 1943). The children appeared to be in their own world and parents reported difficulties in gaining their attention. Whilst the children with autism demonstrated a diminished interest in people, Kanner also noted how objects appeared to be of much greater interest to the children, as they rushed to certain objects in a room and ignored the people present. In current diagnostic terms, ASD is a pervasive developmental disorder that is characterised by difficulties in social communication and interaction, and restricted and/or repetitive behaviours and interests (American Psychiatric Association, 2013; World Health Organization, 1992). The social difficulties include deficits in social-emotional reciprocity, in non-verbal communication, and in developing, maintaining and understanding social relationships. The repetitive and restricted behaviours and interests may manifest as stereotyped or repetitive movements, use of objects or speech; insistence on sameness, inflexible adherence to routines, or ritualised patterns of behaviour; highly restricted, fixated interests that are abnormal in intensity or focus; hyper or hyposensitivity to sensory input or unusual interests in sensory aspects of the environment (American Psychiatric Association, 2013). Diagnostic measures for ASD look for deficits in reciprocal play, turn taking, language and communication whilst observing the child (Autism Diagnostic Observation Schedule, ADOS; Lord et al., 1989). An adult module of the ADOS was also developed to enable diagnosis later in life (Lord et al., 2000). Alternatively (or additionally), an interview with the primary care giver gives a lifespan perspective on behaviours around social interaction (e.g. emotional sharing and offering, and seeking comfort), communication and language differences (e.g. conversational interchange and idiosyncratic language use) and repetitive, restricted and stereotyped behaviours (e.g. rituals and unusual sensory interests) (Autism Diagnostic Interview, ADI; Le Couteur et al., 1989).

ASD is considered a spectrum disorder with individuals affected displaying differing levels of severity (American Psychiatric Association, 2013). At the less severe end of the spectrum is Asperger's Syndrome (AS; although this diagnosis is no longer administered, see below), where affected individuals do not display a delay in language development. At the more severe end of the spectrum are individuals with severe intellectual disabilities who are unable to live independently and may completely lack verbal communication skills. Along with the social-communication difficulties associated with ASD, some individuals also outperform the general population in specific areas and display savant skills (Howlin, Goode, Hutton, & Rutter, 2009). Thus in some aspects of life, individuals with ASD appear to show deficits, yet in others show superior performance. This makes ASD a particularly complex disorder and as such it has generated a lot of research to aid further understanding and to investigate potential areas for intervention to improve the lives of those affected.

Although the International Classification of Mental and Behavioural Disorders 10 (ICD-10, World Health Organization, 1992) is more widely used in clinical diagnosis internationally (Mezzich, 2002), the Diagnostic and Statistical Manual of Mental Disorders (DSM, American Psychiatric Association, 2013) remains influential both in research and practice. In 2013, the DSM-5 superseded the DSM-IV and brought about important changes to the diagnostic criteria of ASD. Under the DSM-IV, separate diagnoses of AS and Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) existed as well as Autistic Disorder. The DSM-5 has removed the diagnoses of AS and PDD-NOS to remove confusion around the different diagnoses, and has instead renamed Autistic Disorder 'Autism Spectrum Disorder' and specified levels of severity in relation to the support required by the individual receiving a diagnosis. Whilst this loss of a diagnostic term has not been welcomed by some individuals with a diagnosis of Asperger's (Giles, 2014), many researchers and clinicians questioned the ability of the DSM-IV to distinguish between AS and ASD (e.g. Mayes, Calhoun, & Crites, 2001; Tryon, Mayes, Rhodes, & Waldo, 2006) and it is likely that the current changes may make diagnoses more straightforward for individuals affected. The term ASD will be used throughout this thesis as an umbrella term to include AS and PDD-NOS, to reflect the current changes in the DSM 5.

1.1.2 Prevalence and gender ratio

The prevalence of ASD is estimated to be between 1% and 2.64% of the population (Baird et al., 2006; Kim et al., 2011), with many suggesting that the prevalence has been increasing in recent years (Matson & Kozlowski, 2011). Reasons suggested for the increasing prevalence are changes in diagnostic methods (King & Bearman, 2009), possibly leading to improved screening, and an increase in awareness of the disorder meaning more people are seeking diagnosis (Kogan et al., 2009). ASDs are frequently reported as being more prevalent in males than females, with ratios of male to female incidence ranging from 4:1 in older studies

(Ehlers & Gillberg, 1993) to 2.69:1 in 2014 (Baker, Milivojevich, Kraycar, Holt, & Gade, 2014). Possible explanations for the gender disparity are that ASD is often misidentified in females who have higher functioning autism because females may be more socially skilled than their male counterparts (Koenig & Tsatsanis, 2005), and have fewer restricted or repetitive behaviours (Mandy et al., 2012) leading to under-identification. Additionally, the male to female ratio diminishes when looking at only ASD with additional learning difficulties (Rivet & Matson, 2011). Therefore, an alternate suggestion is that when autism does affect females, it does so more detrimentally than males, with a possibility that sex chromosomes are implicated (Werling & Geschwind, 2013).

1.1.3 Difficulties associated with ASD

Individuals with ASD have been reported to experience an impaired quality of life relative to typically developing peers. One study reported that parents of children with ASD had greater levels of concern around their children's well-being than parents of children with ADHD or healthy controls (Lee, Harrington, Louie, & Newschaffer, 2008). These concerns included being bullied by peers and learning difficulties, and overall these families with children with ASD experienced poorer quality of life than comparison families. Individuals with ASD also report feeling different from peers, and a resulting sense of isolation from this (Cesaroni & Garber, 1991), with greater loneliness and poorer friendship quality in children with ASD compared to typically developing peers (Bauminger, Shulman, & Agam, 2003; Locke, Ishijima, Kasari, & London, 2010). Therefore, it can be seen that a lot of the difficulties impacting the lives of those with ASD stem from problems relating to other people. Sterling, Dawson, Estes, and Greenson (2008) found that in participants with ASD, higher levels of social skill and greater cognitive ability were associated with an increase in depressive symptoms. This is suggested to be because of an increase in awareness of their social difficulties and differences from peers. These studies highlight the importance of research that can uncover mechanisms behind the social difficulties experienced by people with ASD in order to facilitate interventions which can improve social outcomes.

1.2 The Subclinical autism spectrum

The traits associated with autism are not limited to those with a clinical diagnosis. Bolton et al. (1994) reported that first degree relatives of individuals with ASD show familial aggregation of a 'lesser variant' of symptoms seen in ASD. Relatives exhibited more social and communication deficits and more stereotyped behaviour as measured using a family history interview than relatives of those with Down's syndrome. A broader phenotype was associated with impairments in one of these three areas, and was evidenced by the mild presence of two or more behaviours, or the severe presence of at least one behaviour relating to the domains of social and communication deficits and stereotyped behaviour. The Broader Autism Phenotype (BAP) is a term used to describe the milder symptomology of autism traits found in close relatives of those with ASD (Piven, Palmer, Jacobi, Childress, & Arndt, 1997). Piven and Sasson (2014), in a response to a paper examining the validity of a measure of the BAP, clarified the differences between the BAP and ASD. Traits seen in the BAP are not clinically significant and may differ qualitatively along the same dimension from those in ASD. The authors illustrate this with an example in the domain of restricted interests and repetitive behaviours where a father displaying the BAP may choose to eat in the same restaurant every Saturday night, compared to an individual with ASD displaying repetitive echolalia. In Piven et al.'s (1997) study, using the same family history interview and criteria as in Bolton et al. (1994), it was found that relatives in families where there was multiple-incidence of ASD, both first and second degree relatives displayed higher levels of social and communication difficulties and stereotyped behaviour than families with a child with Down's syndrome. This is taken to be indicative of a greater genetic liability for autism in multiple incidence families. This followed on from Couteur et al. (1996) who found that expression of a broader autism phenotype, demonstrated by language and social deficits, was greater in monozygotic twins of individuals with ASD than in dizygotic twins. This finding has been replicated, with Losh, Childress, Lam, and Piven (2008) finding greater expression of the BAP in families with multiple incidence of ASD compared to families with single incidence, or families with Down Syndrome. The phenotypic expression was found to be related to domains of rigidity, language, sociability and anxiety. Identifying heritable traits in the BAP can help to identify genes associated with ASD.

The research exploring the extent of genetic liability for a BAP has uncovered gradients of expression in relation to genetic similarity to the individual affected by ASD. In addition, it has been proposed that all individuals, regardless of whether they have a relation to someone with a diagnosis of ASD, fall on a spectrum of behaviours and personality correlates associated with ASD, with clinical ASD being an extreme end of this spectrum (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Posserud, Lundervold, & Gillberg, 2006). This idea extends the clinical spectrum where ASD diagnoses are given in terms of severity (or formerly the less severe AS as opposed to Autistic Disorder), to propose a continuum of autism traits across the entire population. The Autism Spectrum Quotient (AQ) was developed to measure the extent to which adults with an IQ of above 85 (Ruzich et al., 2015) display traits associated with autism (Baron-Cohen, Wheelwright, Skinner, et al., 2001). This self-report questionnaire includes subscales of social skill, attention switching, attention to detail, communication and imagination providing a total score out of 50. Baron-Cohen et al. (2001) propose that those scoring 32 or above are likely to have clinically relevant levels of autism traits as 80% of their ASD sample scored 32 or higher compared with only 2% of controls, with the majority of the typically developed population scoring around a mean of 16.4. More recently, in a systematic review of 73 studies comprising over 6,900 typically developing participants, Ruzich et al. (2015) found the mean AQ score in this population to be 17.

Constantino and Todd (2003) also argue that subclinical autism traits are exhibited in the general population. Parent report measures of autism traits in 788 twin pairs (without ASD) were completed, and autism traits were found to be heritable and continuously distributed. The authors highlight the utility of measuring subthreshold autism traits in genetic studies of autism, and in enabling researchers to recruit larger sample sizes. Additionally, they note the importance in measuring subthreshold traits in exploring their implications for social functioning in typically developing children. Constantino and Todd (2005) found further evidence for the continuous distribution of autism traits and their heritability in adults. A measure of parent- and spouse-report autism traits was completed for 285 twin pairs and their parents. It was found that children of two parents who both score highly on the measure of autism traits were 11 times more likely to have clinically relevant levels of autism traits and also more likely to display a greater number of subthreshold traits. Autism traits were found to be highly heritable, particularly in males (Constantino & Todd, 2005).

The idea of a spectrum of autism traits in the general population is also supported by Posserud et al. (2006) who explored the continuum of autism symptoms using the Autism Spectrum Screening Questionnaire (ASSQ). Responses on the ASSQ were received from teachers for over 9000 children and from parents for over 6000 of these. The authors conclude that autism traits in the general population are continuous with a higher number of children scoring lower on the measure and fewer children scoring higher. This corroborates the work of Baron-Cohen, Wheelwright, Skinner, et al. (2001) by showing that autism traits are distributed throughout the general population. Kanne, Wang, and Christ (2012) also support the notion of a subclinical autism spectrum and highlight its utility in research to aid the understanding of clinical ASD. The authors developed the Subthreshold Autism Trait Questionnaire (SATQ) to measure autism traits in the general population. They argue that the study of individuals with subthreshold traits of a disorder allows researchers to uncover differences that are also present in the clinical disorder, and suggest that a broader range of experimental methods may be used with less distress in those with subclinical traits. Nishiyama et al. (2013) compared four measures of what the authors term ‘quantitative autism traits’. These are autism traits across the full spectrum including clinical and subclinical. It was found that all four measures showed a normal distribution of autism traits in the general population, further supporting the notion of a continuous spectrum of autism traits.

Measures of traits associated with autism such as the AQ and the Broader Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick, & Piven, 2007) have been used to look at the extent to which cognitive differences associated with ASD continue down the spectrum. This enables researchers to potentially identify how and why autism develops through looking at differences between those with high levels of autism traits or the BAP and those with a clinical diagnosis of an ASD (Elsabbagh, Volein, Holmboe, et al., 2009). The present thesis comprises 6 studies investigating differences between those with high and low levels of autism traits in the general population and between individuals with ASD versus control participants. The comparison of findings, therefore, may help to illuminate any similarities or differences between those above and below the clinical threshold for ASD.

1.3 Theories of autism

There is currently no universally accepted and comprehensive explanation for the development of autism. Whilst there is general consensus in the field that there is an underlying genetic cause to the observable symptoms associated with ASD, Morton and Frith (1995) highlight the importance of considering a cognitive level between the biological causes and behavioural symptoms of ASD. The authors argue that the majority of theories of autism develop from the perspective that genetic differences lead to neurological differences in ASD which in turn result in cognitive differences manifesting in the behavioural exhibition of symptoms. An understanding of the cognitive differences in ASD, which the present thesis aims to contribute to, may help to elucidate underlying neurological differences in ASD and also provide a point of entry for effective intervention. There are many theories as to how ASD develops from the fields of genetics, neurology and cognitive psychology, but no single theory has been found to hold true for every individual with autism and explain all of the diagnostic criteria. Some argue that this is because the diagnostic impairments in social communication and interaction, and repetitive behaviours in ASD are separable and not necessarily related with each other showing only small to moderate correlations in measures of traits in those domains (Happé & Ronald, 2008; Happé, Ronald, & Plomin, 2006). Happé suggests that theories of autism should strive to account for just one strand of the impairments found in ASD rather than trying to form an all-encompassing theory. Indeed this is what the majority of theories outlined below have achieved and a major criticism levelled at the majority of cognitive theories is their inability to account for all domains of impairment in ASD. The sections below give an account of the major theories of autism and are divided into biological theories encompassing genetics and neurology, and cognitive theories.

1.3.1 Biological Theories

1.3.1.1 Genetics

High heritability rates coupled with autistic presentation in known genetic disorders such as Fragile X and Rett syndromes suggest underlying genetic factors in the development of this disorder. However, the genetic basis of ASD is a complex area and genes are implicated in a number of ways. Miles (2011) states that in only approximately 20-25% of cases can a particular genetic cause be identified. No one genetic abnormality has been identified to implicate a specific ‘autism gene’ and abnormalities have been found on nearly every chromosome (Miles, 2011), with 200-1000 genes identified in susceptibility to develop ASD (Chen, Peñagarikano, Belgard, Swarup, & Geschwind, 2015). However, Chen et al. (2015) present a positive view of the current state of identifying genetic markers for ASD as new technological advances are improving researchers' ability to identify genes. They highlight the fact that studies lead to a 'many genes common pathways' hypothesis where a deficit in neural development leads to abnormal cortical development.

1.3.1.2 Deficits in the 'Social Brain'

Particular regions of the brain have been identified as playing specific roles in social behaviour. The major brain regions identified are the amygdala, the orbitofrontal cortex, the superior temporal sulcus (Baron-Cohen et al., 2000), and the fusiform gyrus (Kanwisher, McDermott, & Chun, 1997).

The amygdala is associated with drive and emotions and is particularly responsive to fear. It has been linked to social behaviour in primates and amygdala volume is related to social group size (Baron-Cohen et al., 2000). The Amygdala Theory of autism developed from evidence that patients with amygdala lesions display autistic like symptoms, and removal of the amygdala produces an animal model of autism (Baron-Cohen et al., 2000). Additionally, fMRI scanning revealed that participants with ASD showed reduced amygdala activation whilst performing a task of mentalizing ability (the Reading the Mind in the Eyes task, see Theory of Mind account below) and that they also performed worse on this task compared to controls. Baron-Cohen et al. conclude that abnormality in the amygdala plays a key role in autism. This theory has been widely researched and a largely corroborating body of knowledge has established support for amygdala abnormality in ASD. Schultz (2005) argues that developmental abnormalities in the amygdala have a cascading effect on the development of the fusiform face area (FFA) which specialises in face processing, whereby ASD is characterised by deficits in social cognition as a result of under development in this area. Amygdala differences are also found to relate to visual attention in ASD with individuals with ASD exhibiting greater amygdala response when fixating on eyes relative to typically developing controls (Kliemann, Dziobek, Hatri, Baudewig, & Heekeren, 2012).

The superior temporal sulcus (STS) is involved in social perception, the perception of biological motion, and some social cognition (Saitovitch et al., 2012). Children with autism have been found to have a decrease in grey matter in the STS (Boddaert et al., 2004) as well as abnormal activation during tasks of social cognition (Zilbovicius et al., 2006). It is thought that neuroanatomical atypicalities during brain development in the STS may lead to other neural differences associated with ASD such as amygdala dysfunction (Zilbovicius et al., 2006). Within the STS, a specific type of neuron has been identified that may be implicated in the development of ASD. Mirror neurons were first identified in the STS of monkeys and it was found that they code for movements of the body. They were also found to activate when observing another monkey performing an action, thereby firing when one monkey performs an action, but also when they observe another performing the same action. It is thought that mirror neurons are implicated in the development of imitative behaviour in humans, which is linked to social development, and imitation is found to be impaired in ASD (Williams, Whiten, & Singh, 2004). The Mirror Neuron theory of autism suggests that early deficits in the mirror neuron system result in downstream developmental difficulties associated with ASD (Williams, Whiten, Suddendorf, & Perrett, 2001).

The orbitofrontal cortex (OFC) is thought to be linked to the ability to interpret emotions from visual cues (Bechara, Damasio, & Damasio, 2000) and as such is linked to theory of mind, the ability to understand another's perspective (Sabbagh, 2004). The OFC is also linked to decision making (Bechara et al., 2000). Decreases in grey matter in the OFC related to social deficits have been identified in MRI studies (Girgis et al., 2007), however, Hardan et al. (2006) found no anatomical differences in the structure of the OFC in participants with ASD but suggested there may be age related differences in the right lateral OFC in ASD. They did find that increases in volume of the OFC structures was related to greater symptomology related to circumscribed interests (CIs) as identified by the ADI.

Finally, an area of the fusiform gyrus, known as the FFA has been identified as showing activation specifically when looking at faces (Kanwisher et al., 1997; Kanwisher & Yovel, 2006). However, in ASD the FFA has been found to show hypoactivity in response to faces relative to typically developing controls (the FFA is discussed in more depth in Chapter 2) (Schultz, 2005).

1.3.2 Cognitive Theories

1.3.2.1 Theory of Mind

One of the earliest cognitive theories of autism focused on the social impairment found in ASD. The Theory of Mind (ToM) account of autism (Baron-Cohen, Leslie, & Frith, 1985) suggests that individuals with ASD are 'mind blind' in the sense that they are not able to understand what other people think and feel. This is cited as a main cause for the social difficulties encountered in ASD and the lack of imaginative play. Baron-Cohen et al. (1985) found that 80% of their ASD group did not pass a theory of mind task which involved taking the perspective of another person (the Sally-Ann task), and so were unable to put themselves in the position of another person. It is suggested that this group difference means that individuals with ASD are less able to predict the behaviour of other people and so would suffer socially. Due to ceiling performance in the test of ToM in this study, and the fact that a number of people with ASD were still able to pass such tasks, Happé (1994) developed a novel task to test the ToM account of ASD. Participants completed the Strange Stories task which described a situation in which a person makes a statement that is not meant literally, for example describing a person as having a frog in their throat, and the participant is required to state whether what was said was true and why the person said it. Participants were young adults and adolescents with ASD who previously either passed a first order theory of mind task but failed a second order one (which involves considering what one person is thinking about what another person is thinking), passed both first and second order theory of mind task, or failed both. These groups were compared with a control group with intellectual disability, typically developing children, and typically developed adults. Both the ASD groups who had failed second order tasks or both types of task were impaired in their performance on the Strange Stories task relative to child and intellectual disability control groups. The participants with ASD who passed first and second order tasks were impaired in their performance relative to the adult control group. Therefore the Strange Stories provided a more sensitive measure of ToM ability and confirmed that this ability is diminished in ASD. Happé (1994) links this finding to the Weak Central Coherence (WCC, see below) theory as well as the ToM account of ASD. She argues that the inability to process the non-literal meaning of the statements in the Strange Stories is a result of a tendency to focus on details rather than global context. In this way ToM deficits could be explained by the WCC theory.

Baron-Cohen, Jolliffe, Mortimore, and Robertson (1997) further built on this work to create a measure of ToM that was more sensitive to previous tasks and related to face perception. The Reading the Mind in the Eyes task involved participants inferring a person's state of mind from a photograph of their eyes. People with ASD were found to be impaired in performance on this task relative to controls which supported the concept that individuals with ASD demonstrate a reduced theory of mind (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). Subsequent studies continue to develop further ways of measuring theory of mind with ASD groups performing worse than controls on these tasks (e.g. Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999; Heavey, Phillips, Baron-Cohen, & Rutter, 2000). However, whilst as a group the participants with ASD may perform worse than the control participants on ToM tasks, there is still overlap between the highest performing ASD participants and the lowest performing control participants suggesting that whilst there may be ToM deficits present in ASD, these are not sufficient to determine the social deficits in the clinical presentation of ASD. Additionally, the ToM account of ASD has been criticised for taking a one dimensional approach to explaining all the symptomology associated with ASD as it is less able to account for the restricted interests/repetitive behaviour element of impairments in ASD (Frith & Happé, 1994).

1.3.2.2 Executive Functioning

Executive functions refer to cognitive processes such as working memory, shifting set, inhibition of irrelevant responses, impulse control, planning and flexibility of thought (Ozonoff, Pennington, & Rogers, 1991). Ozonoff et al. (1991) liken symptoms of ASD such as rigidity and resistance to change to deficits in executive functioning. To test whether ToM, executive functioning or emotion processing were a primary deficit in ASD, Ozonoff et al. administered tasks corresponding to each domain to participants with ASD and chronological age, sex and verbal IQ matched controls. The participants with ASD were found to show deficits in all three domains but the authors conclude that executive dysfunction, as measured by the Tower of Hanoi task and the Wisconsin Card Sorting Task, were primary to both 'classic autism' and Asperger's. All participants with ASD scored below the control group's mean on these tasks whereas some participants with ASD were still able to pass the ToM tasks and some controls did not perform well on them. However, executive functioning difficulties do not appear to be specific to ASD as they are often found in those with ADHD, for example (Hill, 2004). Therefore whilst executive functioning deficits may account for some of the behaviours seen in ASD such as inflexibility of thought, it may not account for the full range of symptomology displayed.

1.3.2.3 Weak Central Coherence

Frith and Happé (1994) put forward an additional account termed Weak Central Coherence (WCC). The WCC theory attempts to explain both the deficits and superior abilities reported in ASD which were not accounted for by the Executive Dysfunction theory of autism. The term central coherence refers to the tendency to understand and remember things at a general global level, rather than specific details. Frith and Happé (1994) suggest that this typical processing style is not present in ASD. They cite evidence from embedded figures tasks, where one has to ignore the general overall image to identify shapes embedded within them. In such tasks, ASD participants frequently outperform typically developing controls, which is interpreted as evidence for a more detail focused processing style. Similarly, individuals with ASD perform worse than controls on tasks that require global processing rather than a more features based approach, such as using the context of a sentence to determine the correct pronunciation of a word, e.g. "bow" in "he had a pink bow" or "he made a deep bow". It is suggested that there is a cognitive difference rather than a cognitive deficit in ASD because of the profile of strengths and weaknesses (Happé, 1999). The authors suggest WCC alongside theory of mind deficits account for the full profile of differences in ASD rather than just the social deficits accounted for by ToM deficits alone (Happé & Frith, 2006).

1.3.2.4 Enhanced perceptual Functioning

The Enhanced Perceptual Functioning (EPF) account of ASD (Mottron & Burack, 2001; Mottron, Dawson, Soulières, Hubert, & Burack, 2006) proposes that individuals with ASD have superior perceptual abilities to typically developing people. It is similar to the WCC theory in that the authors agree that local processing is superior to global processing in ASD, however Mottron et al. argue that this is a result of superior visual processing rather than a deficit in interpreting global meaning. It is argued that this enhanced perception leads to the local, detail focused, bias reported by Frith and Happé (1994). It is also thought that the exceptional talents seen in savant syndrome in persons with ASD could be the result of EPF (e.g. perfect pitch). Mottron et al.

suggest that atypical sensory behaviours in ASD, such as looking at objects out of the corner of the eye or waving the fingers in front of the face, may be an attempt to reduce sensory input which would otherwise be overwhelming. The EPF theory is supported by evidence for superior visual processing in ASD. For example, Bertone, Mottron, Jelenic, and Faubert (2005) found that people with ASD demonstrate superior ability compared to typically developing controls in distinguishing the orientation of stimuli when this was determined by luminance contrast, but impaired relative to controls when the orientation of the stimuli was determined by texture. The luminance task is known to involve processing in the receptive field of only one area of the visual cortex (area V1), and luminance can be determined by a single neuron in this area (Bertone et al., 2005). However, the texture discrimination task is known to require integration from more than one receptive field. Bertone et al. suggest that it is the enhanced perceptual abilities in the simple visual discrimination tasks that are unique to ASD, and that the pattern of enhanced simple visual discrimination and diminished complex visual discrimination are the result of atypical neural connectivity.

1.3.2.5 The Extreme Male Brain Theory

Whilst the ToM account of ASD was able to account for the social difficulties making up part of the diagnostic criteria, it did not offer an explanation as to why individuals with ASD exhibit restricted interests and repetitive behaviours and interests (RRBI). Baron-Cohen built on his ToM account to encompass the RRBI elements of symptomology and account for the detail focused processing style in ASD that the WCC theory had elucidated.

The Empathising-Systemising theory proposes that individuals fall on a continuum of two trait domains relevant to ASD, and that this helps to explain how clinical ASD is not necessarily discrete from the spread of traits in the general population (Baron-Cohen, 2009). The domain of empathising relates to an individual’s ability to identify the mental states of others (cognitive empathy) and to have an appropriate emotional response to these (affective empathy). This builds on the ToM account which accounts only for the cognitive component of empathy (Baron-Cohen, 2009). Systemising is defined as an individual’s drive to create or analyse systems which involves looking for rules and patterns in or between objects, concepts, natural phenomena, and motor behaviours, for example. Baron-Cohen (2009) argues that males and females demonstrate different levels of these two traits. In studies using the Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004) and the Systemising Quotient (SQ; Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003) as well as behavioural tasks to measure empathising and systemising, it has been found that females demonstrate higher levels of empathising with lower levels of systemising, whereas males show the opposite pattern (Baron-Cohen et al., 2003; Baron-Cohen & Wheelwright, 2004; Carroll & Chiew, 2006; Cook & Saucier, 2010; Nettle, 2007).

The concept of sex differences in empathising and systemising in the general population is extended into the Extreme Male Brain (EMB) theory of autism (Baron-Cohen, 2002). This theory suggests that individuals with ASD have an extreme 'male type' brain with very low levels of empathising and very high levels of systemising, and that this EMB is evident in both males and females with ASD (Baron-Cohen, 2009). Baron-Cohen (2002) suggests that it is this drive to look for systems, or patterns, in things that causes individuals with ASD to exhibit detail focused processing as this is the best way of identifying them. Lawson, Baron-Cohen, and Wheelwright (2004) tested this theory with a group of males with AS and males and females from the general population. Participants completed tasks relating to empathising and systemising. To complete the systemising task, participants had to indicate how a lever would move in response to another one moving in mechanical diagrams. For the empathising task, participants completed the Social Stories Questionnaire in which participants have to indicate whether they think that a statement made by a character may upset another character. It was found that females performed better than both male groups on the empathising task and worse on the systemising task, that males without AS performed worse than females on empathising but better than the males with AS, and better than the females at systemising but equally as good as the males with AS, and the males with AS performed better than the females on the systemising task and worst on the empathising task. This supports the EMB theory by showing that individuals with AS demonstrate a deficit in empathising and at least average skills in systemising. The EMB profile was also supported by Wakabayashi et al. (2007) who administered the SQ and EQ to people with ASD, students, and people from the general population. The ASD group was found to have lower scores on the EQ than control participants, and higher scores on the SQ. Similarly, Johnson, Filliter, and Murphy (2009) found that children with ASD scored significantly lower on the EQ than typically developing children, but that there was no difference between groups in systemising. The authors suggest that no group difference in systemising may have been evident because of diminished construct validity of the SQ in the child sample measured. While the majority of research has generally supported this theory, such findings lead some to question the validity of the empathising and systemising dimensions. Andrew, Cooke, and Muncer (2008) argue that systemising is not dimensionally opposite to empathising, and better dimensions to consider would be empathising and Machiavellianism, although this does not necessarily relate to ASD. However, the EMB theory does not necessarily state they are opposite as it is acknowledged that individuals may have equal levels of empathising and systemising demonstrated in the 'balanced brain' (Baron-Cohen, 2002).

1.3.2.6 The Social Motivation Theory

In a related vein, research began to develop suggesting that deficits in social cognition, such as ToM tasks, may emerge as a result of a diminished interest in social information in ASD. Some of the first proponents of this view, Klin, Jones, Schultz, Volkmar, and Cohen (2002) found that participants with ASD fixated less on eyes whilst watching clips from a movie and the authors suggest that social stimuli have reduced salience in ASD relative to typical development. The first to explicitly lay out the theory that ASD is associated with a reduction in social motivation, Dawson, Webb, and McPartland (2005) review the face processing literature and suggest that deficits in face processing in ASD may stem from a primary deficit in social motivation. Essentially, a decrease in interest in social information due to an impaired reward response to social information leads to a decrease in attention to social information, leading to a reduction in expertise and cortical specialisation in face processing. This in turn contributes to social difficulties seen in ASD such as difficulty in reading emotional expressions and in knowing when it is appropriate to speak. This theory ties in with research previously mentioned implicating hypoactivity of the FFA in response to images of faces (Schultz, 2005).

These findings relating to social behaviour in ASD have recently been synthesised into The Social Motivation theory of autism (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). This theory proposes that social difficulties do not emerge from a different cognitive style in ASD, as proposed by the ToM account for example, but from a lack of social motivation which leads to these cognitive differences downstream. The authors highlight that in typically developing individuals, behavioural manifestations of social interest are observed, such as the orientation of attention towards social stimuli, seeking and liking social interaction, and that individuals seek to create and maintain social relationships. Chevallier et al. review evidence showing that all three of these domains are reduced in ASD. Evidence for a reduction in social orienting comes from eye tracking studies such as Klin et al. (2002) mentioned above, and Riby and Hancock (2008) who found that participants with ASD spent less time fixating on people, particularly faces, whilst viewing natural scenes (see chapter 2 for a thorough review of the social orienting element). A diminished interest in seeking out social interactions and finding them rewarding in ASD is demonstrated by a reduction in attempts to share attention with other people in ASD (Mundy & Newell, 2007). Less desire to create and maintain social relationships in ASD relative to typical development is shown in behavioural studies where people with ASD do not moderate how they are perceived by other people as effectively or to the same extent as typically developing individuals (Barbaro & Dissanayake, 2007).

The Social Motivation theory is not incompatible with other theories and incorporates the concepts of a ToM deficit as well as WCC in relation to face processing whereby individuals with ASD tend to process faces from individual parts rather than as a whole. In addition, although Chevallier et al. acknowledge that the theory lacks the ability to account for the non-social features of autism directly, it is possible that a diminished interest in the social world and an increased interest in the non-social world of objects may contribute the RRBI domain of autism symptomology (e.g. as argued by Sasson & Touchstone, 2013). As such, the present thesis is grounded within the EMB and Social Motivation theories to relate to social and non-social interests in the autism spectrum. These theories would suggest that differences in attention are the result of interest and reward value related to specific categories of stimuli in people with ASD, rather than the result of general differences in attentional style as would be suggested by WCC or EPF theories.

Chapter 2
Literature Review

Chapter Abstract: Chapter 2 lays out the fundamental aspects of attention that underpin the studies presented throughout this thesis, and their roles and time courses. The special case of social attention is then considered with a discussion of atypicalities in ASD. Circumscribed interests, part of the restricted and repetitive behaviours and interests profile of ASD, are then discussed and research exploring attention to these are presented. Finally research aims of the thesis are outlined.

2.1 Visual Attention

Attention is the means by which the continuous stream of sensory input received by sense organs is narrowed down so that only important parts of this data reach our cognitive processes. Attention is a mediator between perception (receipt of sensory data through the sense organs) and cognition (mental processes). In this way, attention is influenced by both the external and internal worlds and is allocated to areas of the environment that are most relevant to an individual via top down and bottom up processes (Knudsen, 2007). Attending to an area in the visual field ensures that this area is given priority in the visual cortex meaning that behaviourally relevant information is processed to a greater extent than irrelevant information in the environment (Rybak, Gusakova, Golovan, Podladchikova, & Shevtsova, 1998). The present thesis is concerned with whether attention is preferentially allocated to social and non-social objects in ASD. Therefore the following section outlines how attention is guided as a basis for considering attention to social and non-social objects. Attention to social information in typical development and ASD, and attention to non-social objects which may be of more interest to people with ASD are then considered.

2.1.1 Selective Attention

When perceiving the visual environment, the brain does not have the capacity to process every element in detail. Selective attention is the act of attending to particular information in the visual field whilst filtering out irrelevant information (Desimone & Duncan, 1995). Selective attention can be driven by either properties of the visual stimulus, termed bottom up selection, or it can be goal directed in relation to the interests and behavioural relevance to the observer, termed top down selection (Egeth & Yantis, 1997). Once an area of the visual field is selectively attended, this allows the information in that area to be processed to a greater degree than the irrelevant information outside the focus of attention (Desimone & Duncan, 1995).

2.1.1.1 Top down and bottom up processes in attention

Selective attention can be guided through bottom up processes related to factors in the visual field, outside of the observer. These can be things like rapid movement, abrupt onset, bright colours, high contrast, or anything that makes a part of the visual field salient (Theeuwes, Atchley, & Kramer, 2000). Selective attention can also be guided by the execution of top down processes whereby the observer is interpreting what is in their visual field and this guides their attention, or when attention is goal directed. Top down attentional allocation can be determined by several factors. These include current goals, long term learned importance of a stimulus (Desimone & Duncan, 1995), expectancy (Corbetta & Shulman, 2002) and reward (Awh, Belopolsky, & Theeuwes, 2012). Thus when attention is guided by top down control, it will be biased towards rewarding stimuli, task relevant stimuli, stimuli that are expected to be seen, or stimuli that are of particular importance to an individual. It is noted that these influences may compete with each other and as such do not operate as a unitary top down system (Awh et al., 2012).

Thus top down shifts of attention are to some extent under greater volitional control than those elicited by bottom up attention. This is demonstrated by Jonides (1981) who found that it was easier to suppress a response to an invalid central cue, which elicits top down processes, than an invalid peripheral cue, which elicits bottom up processes. Bottom up processes can also be modulated by top down processes, in that attention to something that captures attention via bottom up processes, such as a coloured distractor, can be ignored, or the response to it suppressed (Connor, Egeth, & Yantis, 2004). In the natural environment, both top down and bottom up processes interact to determine where attention is allocated. It is thought that bottom up factors have the most influence in visual attention allocation in the first 100ms, and that after this time top down factors begin to exert a greater influence (Connor et al., 2004; Theeuwes et al., 2000).

2.1.2 Orienting Attention

Orienting visual attention is defined as aligning attentional resources with an area in the visual field (Posner, 1980). Posner’s model of orienting attention describes how attention moves and engages, and can be seen as a process of selective attention (Salemink, van den Hout, & Kindt, 2007): when part of the visual field is selectively attended, attention is oriented to it. Posner states that for attention to be oriented, it must first be disengaged from its present location of fixation, shifted, then engaged at the new location (Posner & Petersen, 1990). Each of these three elements of the orienting of attention have been found to relate to separate areas of the brain. The ability to disengage attention is linked to the parietal lobe (Losier & Klein, 2001); the shifting of attention is associated with the superior colliculus; and the ability to engage attention has been found to be related to the thalamus (Posner & Petersen, 1990). Posner argues that these distinct brain regions operate together in order to orient attention. The term orienting is used throughout the thesis to refer to this process as a whole, that is, the action of engaging attentional resources. Posner makes distinctions between overt and covert, and endogenous and exogenous orienting of attention.

2.1.2.1 Overt and Covert Attention

Visual attention can be engaged either overtly with eye movements and the fixation of the object on the fovea (Itti & Koch, 2000), or covertly with no head or eye movements toward the object of attention, for instance when people are said to look at things ‘out of the corner of their eye’ (Posner, 1980; Posner & Petersen, 1990). Posner (1980) claims that the mechanisms of attention and eye movements are separate systems that are related as covertly attending to a location facilitates eye movements to that location. It is suggested that attention shifts covertly before an eye movement begins to that location. In this way, covertly attended points in the visual field are partially processed and facilitate processing once fixation does occur (Henderson, Pollatsek, & Rayner, 1989). Fixations occur at the most important part of the visual scene to enable processing at maximum resolution (Rybak et al., 1998). However, it is still possible to identify objects which are only attended covertly (Henderson, McClure, Pierce, & Schrock, 1997), and, in a measure of attention biases in anxiety, Bradley, Mogg, and Millar (2000) demonstrated that attentional biases towards particular categories of stimuli are still evident without foveation of the stimuli.

2.1.2.2 Exogenous and Endogenous cueing

This orientation of attention to an object of interest can be driven by external (exogenous) or internal (endogenous) processes. Exogenous orienting of attention is reflexive and automatic in response to an external cue, for instance one’s visual attention is immediately drawn towards an object moving rapidly towards oneself (Mayer, Dorflinger, Rao, & Seidenberg, 2004). Endogenous orienting involves the movement of visual attention as a result of the cognitive interpretation of a cue (the cue can be internal or external). For instance, if one sees an arrow pointing in a particular direction, one interprets the symbolic meaning of the arrow and guides their visual attention toward that direction. The cue here is external and requires cognitive interpretation for it to guide visual attention. Exogenous orienting of attention is thought to be automatic and can occur without conscious awareness whereas endogenous orienting of attention requires a controlled process (McCormick, 1997).

Exogenous and endogenous orienting of attention are demonstrated in reaction time tasks where a cue indicates where the location of a target will appear. The cue can be valid, where the target appears at the location indicated, or invalid, where the target appears at the opposite location. Participants show faster reaction times to identify a target at a validly cued location and are slower to detect targets at an invalidly cued location. This illustrates the costs and benefits of a valid or invalid cue and is referred to as a validity effect (Jonides, 1981). Central cueing tasks orient attention endogenously as they direct the participant to a target at the periphery via interpretation of the central cue (usually an arrow) (Posner, 1980). Peripheral cueing tasks orient attention exogenously through the abrupt onset of a stimulus in the periphery. Traditionally this was the brightening of a box in which the target may appear (Posner & Cohen, 1984). Müller and Findlay (1988) suggest that the benefits of an endogenous cue peak between 300-500ms and these cues remain beneficial at longer display times. However, the benefits of exogenous cues peak at 50-150ms declining from around 300ms.

The decline in benefits of an exogenous peripheral cue after 300ms has been termed Inhibition of Return (IoR). IoR occurs when attention is quicker to engage at an unattended location rather than a previously attended location. When a cue is presented for 300ms or longer, participants will be faster to respond to a target at the opposite location rather than the cued location (Klein, 2000). Initially it was thought that the attention system tagged locations in space as already attended and disregarded them in future search for targets (Klein, 1988). Later it was shown that this tagging also applied to objects rather than simply environmental locations as IoR was demonstrated for moving objects (Tipper, Weaver, Jerreat, & Burak, 1994).

2.1.3 Disengaging Attention

The disengagement of attention involves the cessation of fixation of visual processes at a location (Landry & Bryson, 2004) and is driven by top down processes (Theeuwes & Belopolsky, 2012). As such, disengaging attention can be seen as a measure of the significance of an item in the visual field to the observer. The disengagement of attention is observed in peripheral cueing tasks which exogenously cue attention to a spatial location. The participant is then required to engage attention at a different location, meaning that attention must first be disengaged from its current location (Jonides, 1981).

Several top down factors have been identified as influencing the disengagement of attention. Biggs, Kreager, Gibson, Villano, and Crowell (2012) explored properties of objects that affected attentional capture. Participants fixated a centrally presented stimulus and were required to indicate the type of target shown in the periphery. It was found that objects which were considered negative by the observer were slower to be disengaged from (Biggs et al., 2012). The notion of negative stimuli holding attention and causing slowed disengagement is also well documented in the anxiety literature. Images of faces displaying negative emotions are found to elicit slower reaction times to invalid cues in peripheral cueing tasks relative to faces with neutral or positive expressions (Fox, Russo, Bowles, & Dutton, 2001; Mogg, Holmes, Garner, & Bradley, 2008). It is not only negative valence that leads to an increase in latencies to disengage attention. Some argue that rewarding stimuli can also lead to slowed disengagement (Frewen, Dozois, Joanisse, & Neufeld, 2008). This is supported by Tapper, Pothos, and Lawrence (2010) who found that increased hunger in participants was associated with impaired disengagement from food images in a dot probe task, and participants with a greater drive to seek rewards were found to show delayed disengaging from images of foods rated as appetising. However, Theeuwes and Belopolsky (2012) suggest that reward is associated with enhanced automatic orienting rather than slower disengagement. Another factor that can influence the extent to which an object in the visual field holds attention is the expectation of the observer. In visual search tasks, distractors which are more similar to the target, and thus are relevant to the participant's 'mental set' are found to produce slower disengagement than dissimilar distractors (Wright, Boot, & Brockmole, 2015). This therefore suggests that objects in the visual field that are task relevant hold attention to a greater degree. Furthermore, familiarity has been found to influence the extent to which objects in the visual field hold attention. Familiar faces were found to interfere more in a visual search task than unfamiliar faces, and this was found to be the result of an increase in the holding of attention by these stimuli rather than receiving priority in the initial capture of attention (Devue, Van der Stigchel, Brédart, & Theeuwes, 2009). Another factor which impacts the disengagement of attention is arousal. Vogt, De Houwer, Koster, Van Damme, and Crombez (2008) found that stimuli that were rated high in arousal had more impact on the disengagement of attention than the emotional valence of the stimuli. Participants were slower to disengage attention from an image in a peripheral cueing task if rated high in arousal than low in arousal regardless of whether it was rated positive or negative in valence. The authors suggest, therefore, that arousal may account for the difficulty disengaging attention from threatening stimuli. Experiments measuring the disengagement of attention, therefore, highlight the salience of certain objects in terms of expectation, reward, threat, familiarity, or arousal.

2.2 Social Attention in Typical Development and ASD

There is a wealth of research illustrating the special priority that other people and particularly faces are given in the allocation of human visual attention (Bindemann, Burton, Langton, Schweinberger, & Doherty, 2007; Birmingham & Kingstone, 2009; Morton & Johnson, 1991). The term 'social attention' is used variously by authors to describe different facets of looking at people. Social attention is often used to encompass joint attention, whereby an observer's attention shifts to follow a verbal or visual cue to where their communication partner is attended (for example pointing, a shift in eye gaze towards an object, or a verbal command to look at something) (Birmingham, Bischof, & Kingstone, 2008), and Dawson et al. (2004) refer to elements of social orienting, joint attention and attention to the distress of others within social attention. More generally, authors describe social attention as a bias to orient attention to other people (Freeth, Foulsham, & Kingstone, 2013; Guillon, Hadjikhani, Baduel, & Rogé, 2014). The present thesis follows this broad definition and the term Social Attention is used to refer to the allocating of attentional resources to other people.

This attentional bias towards social information is thought to be vital in the development of social skills. An emerging theory of autism postulates that early deficiencies in social attention may lead to diminished cortical specialisation for face processing and social difficulties associated with ASD such as ToM deficits (Schultz, 2005). From Kanner (1943)'s original description of autism, a marked reduction in attention to other people has been observed in individuals with ASD, and the current DSM 5 diagnostic criteria for ASD includes abnormal eye contact (American Psychiatric Association, 2013). In line with the Social Motivation theory of autism (Chevallier et al., 2012), it is thought that possible disturbances in the allocation of attention to social information may contribute to social difficulties in ASD. If individuals with ASD are not motivated to pay attention to social cues from a young age, this may impact on their ability to interpret them and respond appropriately (Dawson et al., 2004). However research findings are not clear cut on whether people with ASD do show atypical attention to social information.

2.2.1 Face Processing in Typical Development and ASD

Before considering how individuals look at social information, how social information is perceived must first be considered. The perception of something in the visual field as a face is thought to occur differently to that of other objects. Attention to faces is thought to be a special kind of attention as it appears that humans can perceive an object as a face rapidly and automatically, and that attending to a face elicits particular neural activation not seen when attending to other objects (Kanwisher & Yovel, 2006).

2.2.1.1 Feature Based and Configural Processing

To consider how faces are perceived, it is important to first consider the visual properties that are used to detect faces and how these differ in typical development and in ASD. It is thought that faces are processed based on the configuration of features within the face, such as the positioning of two eyes above one nose, the space between features, and the consideration of the face as a whole rather than parts (Maurer, Grand, & Mondloch, 2002). That is to say, faces are processed holistically rather than based on the individual features that make up the face (e.g. de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007; Rossion, 2013; Young, Hellawell, & Hay, 1987).

Configural, holistic processing is evidenced by what is known as the face inversion effect. It has been shown that it is much more difficult to recognise a face when it is presented upside down compared to upright, but this effect is not shown for other objects (Farah, Wilson, Drain, & Tanaka, 1995). It is thought that configural processing improves with development, and is slower to develop than processing of faces based on individual features. Mondloch, Le Grand, and

Maurer (2002) found that adult participants relied more on configural information for face processing rather than feature based information in a matching task. Children were found to perform worse on a matching task where configural information was altered, but to a comparable degree to the adults when featural information within the faces was altered. This suggests that although configural processing occurs in infants (Morton & Johnson, 1991), it continues to develop throughout the life course and reaches its peak in adulthood, whereas feature based face processing had already reached adult levels at the age of 6 in Mondloch et al. (2002)'s study. This suggests that configural processing improves with expertise as a person gets older and is consistent with the view that innate subcortical face detection processes in infancy assists humans to attend to faces, and develop cortical specialisation for face processing (Johnson, 2005).

There is evidence to suggest that individuals with ASD tend to process faces based more on features rather than configurally as a whole, but that the ability to process faces holistically is intact when the task demands it. Joseph and Tanaka (2003) explored face processing ability in ASD and typical development. Children had to match either a face part or a whole face to a previously presented target face. The target face was presented either upright or inverted, then a pair of either whole faces or face parts appeared on the screen. One of the whole faces or face parts matched the target face, and the other was altered. The children with ASD were better at matching the target face when presented with whole faces rather than parts only when the feature that was altered in the whole face was the mouth. This implies they were using typical holistic face processing when the feature that was altered was the mouth. Additionally, the participants with ASD did not show an inversion effect when making a matching judgement for whole faces when the feature altered was the eyes whereas the control group did. This suggests that the ASD group have the ability to holistically process faces and that a general deficit in this ability cannot account for difficulties seen in ASD with face recognition. The authors argue that individuals with ASD attend more to mouths than eyes when looking at faces either because of an aversion to looking at eyes or because of difficulties perceptually interpreting information from eyes. It is possible that individuals with ASD are often found to attend to eyes to a lesser degree than typically developing individuals and to mouths to a greater degree due to an aversion to attending to eyes resulting from over arousal from looking at the eye region. Eye gaze has been found to elicit increased amygdala activation in people with ASD compared to typically developing individuals (Dalton et al., 2005) and therefore people with ASD may avoid attending to the eye region. Additionally, Neumann, Spezio, Piven, and Adolphs (2006) suggest that the bias towards mouths found in people with ASD is not the result of increased bottom up saliency of mouths relative to eyes as visual attention to mouths and eyes was found to be comparably influenced by salience manipulation in both participants with ASD and control participants. Instead, they argue that mouths may provide greater facilitation of social understanding compared to eyes. People with ASD have been found to be impaired in interpreting information from eyes relative to typically developing individuals which could be the result of a developmental cascade of reduced social attention whereby people with ASD have a reduced drive to attend to faces, and the eye region in particular (Baron-Cohen, Wheelwright, Hill, et al., 2001; Dawson, Webb, & McPartland, 2005). The notion that people with ASD are able to process faces configurally, but tend to rely more on feature based information is widely supported by other research (e.g. Kikuchi, Senju, Hasegawa, Tojo, & Osanai, 2013; Lahaie et al., 2006; López, Donnelly, Hadwin, & Leekam, 2004). Therefore, research suggests that individuals with ASD are able to process faces holistically and based on configural information, but without task necessity they will tend to process faces in a more local, feature based way, consistent with the WCC theory of ASD.

2.2.1.2 High and Low Spatial Frequency

It is widely accepted that configural processing of faces is supported by the low spatial frequency (LSF) information in faces (Goffaux, Hault, Michel, Vuong, & Rossion, 2005). LSF information provides coarse, configural information relating to gradual changes in luminance within an object, and high spatial frequency (HSF) information in faces shows more detailed information represented by fast changes in luminance such as edges (Goffaux et al., 2005; Vuilleumier, Armony, Driver, & Dolan, 2003).

It is thought that cortical regions such as the fusiform cortex are involved in the processing of HSF information and subcortical regions such as the amygdala are involved in the processing of LSF information (Vuilleumier et al., 2003). LSF information is primarily involved in the detection of a face, and HSF information is most important for identifying a particular individual or particular emotions (Fiorentini, Maffei, & Sandini, 1983; Johnson, 2005; Vuilleumier et al., 2003). Research suggests that face detection relies most on LSF information, however, HSF information is also important and face processing is optimised by the presence of both (Halit, de Haan, Schyns, & Johnson, 2006).

The reliance on feature based processing of faces in ASD is linked to greater use of HSF than LSF information from faces as this conveys more information about the features. Deruelle, Rondan, Gepner, and Tardif (2004) found that participants with ASD made fewer errors when matching the identity of a target face that showed only HSF information than LSF information, and that typically developing control participants displayed the opposite pattern. This showed an increased reliance on the detailed information shown in the HSF frequencies which has been linked to feature based processing of faces. However, there is evidence to suggest that individuals with ASD are still able to use LSF information when helpful to the task. Deruelle, Rondan, Salle-Collemiche, Bastard-Rosset, and Da Fonséca (2008) found that participants with ASD and control participants relied more on LSF information to determine the gender of a hybrid face made form LSF information from one face and HSF information from another. However, when participants were required to either identify the emotion displayed or to match one of two faces to a target face, the ASD group were found to use the information from the HSF face presented in the hybrid face more than the LSF face, whereas controls showed the opposite pattern. This suggests that in general, individuals with ASD will rely more on HSF information which is related to the finer details of a face. However, they are able to attend preferentially to LSF information when it is helpful to the task, such as in gender discrimination, which has been found to rely more on LSF in typical development than more complex discrimination tasks that also require the use of HSF information.

2.2.1.3 Automaticity of Face Detection

In a review of face processing literature, Palermo and Rhodes (2007) question whether face processing is automatic. They argue that for face processing to be automatic it should be some or all of rapid, non-conscious, mandatory and capacity free. The authors conclude that whilst face processing may not occur without conscious awareness and in the absence of attentional resources, it is rapid and certainly appears to be mandatory. Palermo and Rhodes cite evidence from Liu, Harris, and Kanwisher (2002) that the categorisation of objects as faces occurs as rapidly as 100ms after stimulus onset. Additionally, It is thought that faces are processed holistically within as little as 160ms (Jacques, d'Arripe, & Rossion, 2007), and Sato et al. (1999) suggest that activation in the fusiform gyrus in response to faces is also evident in 160ms. This is supported by Crouzet, Kirchner, and Thorpe (2010) who presented participants with pairs of faces with other objects. Participants made saccades towards faces in as little as 100ms despite being instructed to look at the images of other objects. The authors argue therefore that face detection can occur in as little as 80ms as it takes 20ms to send information to, and to move, the eye. These studies highlight the speed at which a face is both recognised as a face and garners attentional resources. Crouzet et al. (2010) also provide evidence for the mandatory nature of detecting faces as participants still attended to them despite instructions to the contrary. Additionally, Lavie, Ro, and Russell (2003) found that increasing perceptual load, which has typically been found to reduce the influence of distractors, lead to a reduction in interference from distractor images of musical instruments but not from faces. This indicates that faces, but not other objects, are unavoidably processed. The authors conclude that faces are special in their ability to capture attention.

However, in ASD, faces may not be detected automatically. Fujita et al. (2013) explored whether face processing is automatic in ASD by examining ERPs when participants were subliminally presented with a face either showing a neutral or fearful expression, or an object. Faces and objects were presented upright or inverted. The typically developing group were found to exhibit an enhanced early (100ms) N1 response to upright fearful faces compared to other objects. The early response of the ASD participants did not differ across stimulus categories. The authors suggest that this may be because of a difficulty interpreting the LSF information in the rapidly presented faces by the ASD group, or a result of the widely reported amygdala dysfunction in ASD (e.g. Ashwin, Baron-Cohen, Wheelwright, O'Riordan, & Bullmore, 2007) which is implicated in the detection of emotional faces. Additionally, Bailey, Braeutigam, Jousmäki, and Swithenby (2005) found that individuals with ASD showed weaker responses at approximately 145ms to faces than control participants using MEG during a matching task. They also found that the cortical areas generating this response to faces overlapped with areas that responded to other objects (e.g. a motorbike). Additionally, the ASD participants did not demonstrate a priming effect in their responses when a second face of a pair was presented whereas the control participants did. It is suggested that participants with ASD were processing the faces in the same way as objects as there was less evidence for a specialised area, and that there is a lack for a fast specialised face processing pathway. This suggests that face processing may not occur as automatically in ASD as it does in typical development. Furthermore, McPartland, Dawson, Webb, Panagiotides, and Carver (2004) found that participants with ASD demonstrated a longer latency to produce an N170 response when viewing images of upright faces relative to control participants. Additionally the ASD group did not show a difference in the latency to N170 in response to upright and inverted faces, whereas the control participants were faster to elicit a response to upright compared to inverted which is interpreted as a benefit of configural processing of the upright faces.

2.2.1.4 Neural Specialisation for Faces

This attentional priority of faces is thought to have neural underpinnings. It is suggested that there are specialised cortical areas devoted to the perception and recognition of faces. It is thought that innate, subcortical mechanisms enable the rapid detection of faces via the amygdala and rely on configural, LSF information (Johnson, 2005). This early mechanism biases attention towards faces, which is thought to lead to the development of specialised cortical regions for face processing (Grelotti, Gauthier, & Schultz, 2002; Johnson, 2005).

However, there is debate as to whether the cortical specialisation is face specific or the result of expertise. Research began to emerge from neurological studies which identified particular regions of the brain that were activated on viewing faces (Sergent, Ohta, & Macdonald, 1992). Kanwisher et al. (1997) examined whether this brain region was face specific in its activation. Participants viewed images of faces, houses, other common objects, human hands, and scrambled faces. fMRI scanning revealed an area in the fusiform gyrus that showed stronger activation to faces than other objects. Kanwisher et al. named this area the Fusiform Face Area (FFA).

However, others have suggested that the FFA may not necessarily be face specific, rather it may show activation for any object category that a person has expertise in. Gauthier, Tarr, Anderson, Skudlarski, and Gore (1999) found that when participants were trained to become ‘experts’ on a novel category of stimuli called Greebles, the FFA was activated when they were making judgements as to whether two Greebles were the same. Greater activation in the FFA was found when the Greebles were presented upright relative to when they were inverted, as is seen in the inversion effect with faces. Wallis (2013) reviews the literature relating to face and object perception. He argues that the effects of cortical and processing specialities for faces are the result of expertise from repeated learning of this category of objects, and that processing factors thought to be specific to faces such as configural processing are developed for any objects of expertise.

In addition to cortical specialisation for faces, there is also evidence to suggest that a proximal area in the fusiform gyrus is specifically implicated in the processing of the rest of the human body. Attending to the bodies of other humans as well as faces is also important in establishing information relating to the person’s identity and intentions (Peelen & Downing, 2007). When participants performed a task where they had to indicate whether stimuli were the same as one shown previously, a distinct area of the fusiform gyrus was activated when making judgements for categories of faces or bodies without heads relative to tools or natural scenes (Peelen & Downing, 2007). However, using fMRI, analysis of regions of interest in the brain found two distinct regions where activation was greater for faces and where activation was greater for bodies. Additionally, when participants completed the matching task with images of stick figure bodies and scrambled stick figure drawings, the body specific region rather than the face specific region of the fusiform gyrus was found to be activated. Support for the fusiform body area also comes from Schwarzlose, Baker, and Kanwisher (2005) who found that the FFA activated selectively to faces and in the fusiform body area to body parts and images of bodies with the heads cropped off when observing images and making judgements about what direction the stimuli were moving in.

Atypicalities in face processing in ASD may be the result of differences in either subcortical or cortical face processing. The automatic ability to detect and orient to faces is thought to be innate in humans and it is suggested that this route is impaired in ASD (Johnson, 2005). Kleinhans et al. (2011) found evidence to suggest that subcortical face processing is atypical in adults with ASD. Participants were presented with images of fearful faces and houses at a pre-determined supraliminal threshold (23ms). The participants had to press a key to indicate whenever a fixation cross was shown and were not informed that faces and houses would be presented. With fMRI scanning, it was found that the ASD group showed reduced activation in the subcortical amygdala, pulvinar and superior colliculi, and the cortical fusiform gyrus when viewing the faces. The authors argue that these subcortical differences in ASD underlie the attentional atypicalities to faces in ASD (discussed below in more detail). However, a contrasting finding in relation to the subcortical processing of faces in ASD was reported by Dalton et al. (2005). It was found that individuals with ASD demonstrated greater amygdala activation in fMRI compared to control participants during emotion discrimination and face recognition tasks.

Additionally, the amount of fixation on the eye region of faces, as measured by eye tracking, was found to be significantly positively related to amygdala activation in the ASD group but not the control group. It is suggested that eye fixation in ASD leads to negative over-arousal and this may be the reason for reduced eye fixation in ASD. This may link to findings which suggest that individuals with ASD are better at configurally processing information from mouths rather than eyes (Joseph & Tanaka, 2003). The difference in results for hyper- and hypoactivation of the amygdala in ASD may relate to eye fixation. It is possible that in the Kleinhans et al. (2011) study the participants did not attend to the eye region during the very brief presentation time and therefore showed hypoactivation rather than hyperactivation.

Additionally, there is evidence to suggest that it is the cortical areas, including the FFA, that are atypical in ASD. Several studies have shown hypoactivation of the FFA in individuals with ASD relative to faces whilst performing face discrimination tasks (Hubl et al., 2003; Pierce, Müller, Ambrose, Allen, & Courchesne, 2001; Schultz et al., 2000). However, when passively viewing faces (Hadjikhani et al., 2004) and when viewing familiar faces (Pierce, Haist, Sedaghat, & Courchesne, 2004), FFA activation in participants with ASD has been found to be comparable to that of typically developing controls. Schultz (2005) suggests that the difference in the findings of Pierce et al. (2004) and Hadjikhani et al. from the majority of other research on the FFA in ASD are the result of task differences which did not involve identity discriminations which are thought to particularly activate the FFA in typical development. Schultz also points out methodological flaws in Hadjikhani et al.'s study such as a significant age difference between the ASD and control groups, the use of stimuli that were too large to view as a whole. Therefore, overall it appears that individuals with ASD do not show typical FFA activation in response to faces.

2.2.2 Face Processing in the Subclinical Autism Spectrum

Differences in face processing abilities have also been found in relation to subclinical autism traits. Adolphs, Spezio, Parlier, and Piven (2008) found that parents of children with ASD who display 'aloof' BAP characteristics demonstrate face processing styles more reliant on the mouth than the eyes, similar to that seen in ASD, using the same methodology as Neumann et al. (2006) reported above. This was not found in parents of typically developing children, or parents of children with ASD who did not possess the aloof characteristics. It is suggested that the BAP is associated with similar atypical face processing strategies to those found in ASD. Yucel et al. (2014) used fMRI whilst participants completed a sequential matching task with faces and other objects to explore neural activation in face processing in parents of children with ASD. It was found that parents of a child with ASD demonstrated increased activation in the fusiform gyrus and amygdala relative to the parents of typically developing children. This is similar to findings in ASD which found increased activation in the amygdala (Dalton et al., 2005). The authors therefore suggest that whilst atypicalities in the amygdala and fusiform gyrus may be necessary for ASD, they are not sufficient. However, the results of this study were not directly compared to an ASD sample so it cannot be concluded whether the differences in amygdala and fusiform gyrus activation were as large as would be found in an ASD sample in this experiment. Outside of the BAP, Hasegawa et al. (2013) found that higher scores on the AQ were associated with greater amplitude responses in the posterior superior temporal sulcus (pSTS) when viewing faces with direct gaze during MEG. The authors do not offer an explanation of why higher levels of autism traits would be associated with increased activation in the pSTS. The pSTS is thought to be specifically involved in interpreting eye contact (Senju & Johnson, 2009). However, abnormal activation in the STS in ASD (although generally this has been found to be reduced) is thought to be associated with difficulties in social cognition as the STS is involved in the interpretation of intention in social interaction and is connected with both the FFA and amygdala (Zilbovicius et al., 2006). Whilst Hasegawa et al.'s study does not offer any concrete conclusions with regards to neural activity in relation to gaze processing, it does indicate that neural activity in social brain areas is related to subclinical autism traits when processing information from faces.

2.2.3 Social attention in Typical Development

Attention plays a large role in the modulation of face processing abilities, and it is thought that a subcortical, innate drive to attend to faces contributes to the development of expertise in faces and the development of social skill (Dawson, Webb, & McPartland, 2005). From birth, infants show a preference to allocate visual attention towards social stimuli. Neonates follow face like patterns with their head and eyes more than scrambled face patterns and blank stimuli (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991), infants from three months of age show a preference for human eyes over primate eyes (Dupierrix et al., 2014), and infants and toddlers look more at faces than other parts of the body or objects (Frank, Vul, & Saxe, 2012). It is thought that giving social information this attentional priority is essential for infants to learn how to interpret, respond to and display social cues. Johnson (2005) argues that the preference of new-borns to look at faces is driven by an innate subcortical preference to attend to these stimuli based on LSF information. This ensures the infant orients towards its caregiver to learn information about its environment and to interact to ensure its needs are met. The subcortical route for face detection matures into the adult social brain through the development of cortical specialisation for faces which is developed through extensively attending to faces throughout development (Johnson, 2005).

Evidence for this preferential looking towards face like stimuli has been found to remain throughout the lifespan. Frank, Vul, and Johnson (2009) found that visual attention to faces increased with age in 3, 6 and 9 month old infants and adults. Adults were found to look the longest at faces whilst viewing cartoon movie clips, followed by 9, then 6, then 3 month olds. The authors suggest that this increase in attention to faces could be the result of increased motivation to attend to faces due to learned importance, or it may represent the developmental ability of attentional control. The youngest infants' looking behaviour was best predicted by salience maps of the scenes as opposed to the location of faces, which better predicted the older participants' viewing patterns. Tomalski, Csibra, and Johnson (2009) tested whether the same attention orienting to schematic faces observed in infants was also shown by adults. Participants were instructed to fixate on a central cross, and a peripheral image of a schematic face (two dark squares above one dark square on a white oval) was flashed for 200ms. The stimuli were presented either upright or inverted, and either as normal or with reversed contrast polarity. It was found that the adult participants were faster to make saccades to the upright faces that displayed typical eye region contrast (black within white representing pupils within sclera) but not the reversed polarity stimuli. This shows that the attention bias towards face like stimuli seen in infants is also present in adults. Fletcher-Watson, Findlay, Leekam, and Benson (2008) measured typically developed adults' attention to natural scenes in which a person either was or was not present. The two types of scenes were presented simultaneously and adjacent to each other. When participants freely viewed the two scenes, eye tracking revealed that participants attended to the person present scene to a greater degree than the person absent scene with the majority of fixations on the person, and that their first fixation was more likely to fall on the person within as little as 100ms. This indicates a strong attentional preference to focus on social information rather than non-social information in scenes in typical development. The findings also suggest that social information captures the rapid orienting of attention.

There is some evidence to suggest that the rapid attentional capture of faces is due to automatic processes. Theeuwes and Van der Stigchel (2006) demonstrated that faces can be automatically attended to in typical development. Their experiment was based on the principle of IoR which occurs only when attention is oriented exogenously rather than endogenously. Participants were presented with pairs of images for durations long enough to elicit IoR, meaning attention was selectively shifted to one of the stimuli. After the offset of the stimuli, a central arrow cue pointing either left or right indicated that the participant should make a saccade in that direction. This meant that attention had to be disengaged from the image that was attended and shift to the central arrow cue, before shifting again in the direction of the arrow. It was found that participants were slower to make a saccade to the location the arrow cue indicated when it pointed to the side where an image of a face had previously been shown than when the previous location of an object image had been displayed. This is indicative that IoR occurred for the face stimuli only. The authors therefore suggest that faces must capture attention exogenously as IoR can only occur under these conditions. The automaticity of attending to faces is also illustrated by the interference on task performance of task irrelevant face distractors. In a visual search task, Simpson, Husband, Yee, Fullerton, and Jakobsen (2014) found that human faces were located faster than primates' or other mammals' faces when presented in arrays among inanimate distractor objects. Additionally, when searching for non-face stimuli among distractors, the presence of a human face distractor was found to produce greater interference than primates or other mammals' faces. The authors argue that this is indicative of bottom up, stimulus driven processing of faces. Faces were task irrelevant and therefore attending them is argued not to be the result of goal directed, top down processes, but rather the result of the stimulus properties. This links to the research reviewed above that suggests the processing of faces is based on configural information (Goffaux et al., 2005) and may occur automatically (Palermo & Rhodes, 2007).

Attention to faces can also be modulated via top down control. Bindemann et al. (2007) found that reaction times were faster to identify a target when it was presented in the location of a face compared to the location of another object in a dot probe experiment indicating an attentional preference for faces over other objects. The experiment was then manipulated so that the target was three times more likely to appear in the location of the object rather than the face. In this experiment, reaction times were faster when the probe was shown in the same location of the object relative to the face. This illustrates that an attentional bias towards faces can be overcome by top down modulation.

As well as faces capturing attention rapidly and automatically, there is also evidence to suggest that once faces are attended, they hold attention for longer than other objects. This indicates a difficulty disengaging attention from faces. Parks, Kim, and Hopfinger (2014) found that both neutral and fearful faces interfere with attention to a target stimulus over long presentation durations. Images of faces or places (houses or rooms) were presented as distractor stimuli in the centre of a display. The participants' task was to identify whether the orientation of a T was either diagonal or vertical/horizontal. Face stimuli which were either neutral or showing a fearful expression interfered with task performance over the course of 4 seconds of presentation time, whereas the images of places interfered with task performance only in the first second. This suggests that faces hold attention to a greater degree than other objects. Further evidence for the attentional holding of faces and body parts was found by Ro, Friggel, and Lavie (2007). The participants' task was to identify a target (a green frame around an image) in an array of six images. Non-target images had a blue frame, and a singleton distractor (a red frame) was shown around one image on each trial. Images of faces and body parts were found to interfere with identification of the target as response times were slower when the irrelevant singleton appeared around face or body part images relative to other categories of objects. The authors suggest that this finding is indicative of greater attentional holding of faces and body parts relative to other objects. Bindemann, Burton, Hooge, Jenkins, and de Haan (2005) also found that faces were particularly difficult to disengage attention from relative to images of other objects. Bindemann et al. (2005) used a Go/No-Go task to explore whether faces retain attention relative to other types of objects. A central signal consisting of a green or red dot was superimposed over an image of a face or other objects. When a green dot was shown, participants were required to indicate whether a vertical line was shown to the left or right of the central stimulus. Therefore these ‘Go’ trials required the disengagement of attention from the central image. It was found that reaction times to locate the target were slower when the central stimulus was an upright face (both familiar and unfamiliar) compared to when it was an inverted face or a non-social object. This was found to be the case when central stimuli were presented for relatively short periods of time (200ms) and longer periods of time (1000ms) indicating that faces not only captured attention but also held it to a greater degree than other objects.

In summary, a wealth of research indicates that faces (and other body parts) receive attentional priority relative to other objects in typical development. This attentional bias towards faces is present at both the rapid, automatic orienting stage, and over longer durations suggesting that once faces capture attention, it remains there. The attention bias towards social information is thought to be vital in the development of social behaviours (Dawson, Webb, & McPartland, 2005). This has led many to explore whether social attention may be atypical in ASD and therefore contributes to the associated social difficulties. Large amounts of research have identified social attention atypicalities in ASD, and atypical social orienting is one of the central tenets of the Social Motivation theory of ASD (Chevallier et al., 2012). The Social Motivation theory suggests that people tend to orient attention towards social information because it contains important information that may either be threatening or rewarding to the observer, but that individuals with ASD do not have these biases (Chevallier et al., 2012). However, there is another line of evidence which finds typical social attention in individuals with ASD and it is argued that social orienting deficits cannot be the cause of the social difficulties associated with the disorder (e.g. Fischer, Koldewyn, Jiang, & Kanwisher, 2013; Johnson, 2014).

2.2.4 Social Attention in ASD

In early work on social attention in ASD, Dawson, Meltzoff, Osterling, Rinaldi, and Brown (1998) examined children’s attention whilst an experimenter presented social or non-social audio stimuli. The social stimuli were calling the child’s name and hands clapping. The non-social stimuli were a musical jack in the box or a rattle being shaken. Video recording of the child was analysed to assess whether the children oriented to the stimuli and the extent to which they showed either immediate (within 2 seconds of stimulus) or delayed orienting. It was found that children with ASD oriented less often in response to both social and non-social stimuli than the control children, but also less often to social than to non-social. Additionally, the children with ASD were found to be more delayed in orienting to social stimuli than control children, but there was no difference between the two groups for non-social stimuli. Dawson et al. suggest that social orienting differences such as these may be one of the earliest emerging signs of autism and a good potential target for intervention to teach children with ASD that social information is important to attend to in order to develop social abilities. This idea was soon corroborated by Klin et al. (2002) who explored spontaneous looking behaviour of adolescents with and without ASD whilst watching movie clips. Participants watched 5 clips from a movie depicting intense interaction between characters and a head mounted eye tracker recorded where participants were looking. It was found that the control group spent significantly more time looking at the eye region of people's faces, whereas the ASD group spent more time than the control participants looking at the mouths and bodies of characters, and at non-social objects in the scene. However it should be noted that the movie scenes were chosen to minimise non-social information in the scene and maximise attention paid to the characters therefore the focus of this study was mainly on attention within the face. Nonetheless it was found that increased fixation on objects was associated with a decrease in social functioning in the ASD group. The authors suggest that this is the result of a diminished salience of social stimuli to individuals with ASD and that further studies should investigate the impact of non-social objects, especially those which particularly attract the attention of people with ASD.

Since these relatively early studies which uncovered atypicalities in social attention in ASD, there has been an explosion of research in this area. Methodologies used are diverse and often reflect different facets of attention. The following section will consider this research in the categories of orientation (do social stimuli immediately capture attention in ASD), disengagement (do social stimuli hold the attention of people with ASD), and general attention (do people with ASD tend to look more at social stimuli than other stimuli overall).

2.2.4.1 Social Orienting in ASD

The term social orienting is used in the present thesis to refer to the tendency to orient towards social information in the visual field over other stimuli. Specifically, it refers to the rapid allocation of attention to this social information after stimulus onset. As such, social orienting relates to the subcortical route for face detection described by Johnson (2005). There is a lack of research which explores this rapid, automatic attention orienting towards social information in ASD.

In one of the few studies which specifically explores rapid, selective orienting to faces, Moore, Heavey, and Reidy (2012) tested this using a dot probe task. In a dot probe task, pairs of stimuli are rapidly presented followed by a target in the location of one of the stimuli after they have offset. Participants' task was to respond to the targets. If participants are faster to respond when the target is shown in the location that had previously been occupied by one category of stimuli than when it is presented at the opposite location, this indicates that attention was engaged at the location of that stimulus. These effects can be compared across different types of stimuli. Moore et al. paired images of faces with images of cars or houses. The stimuli were presented at either individually computed subliminal thresholds, or a supraliminal threshold of 200ms. It was found that there were no differences in attention bias towards faces over other objects between the ASD and control groups when the images were presented subliminally, as neither group showed an attention bias towards faces at this presentation duration. However, when the images were presented for 200ms, the control group were found to display a greater attentional bias toward the faces than the ASD group. Moore et al. suggest that this shows that patterns of reduced attention towards social stimuli seen in infancy and childhood (e.g. as in Dawson et al. 1998) persist into adulthood. Moore et al. suggest that this may be due to a lack of social motivation, despite adults having greater social experience than infants.

However, a contrasting finding regarding the rapid orienting of attention to faces has been found by Shah, Gaule, Bird, and Cook (2013). Using a similar methodology to the dot probe, Shah et al. found evidence to suggest that rapid attention orienting towards faces is intact in ASD. Shah et al. used stimuli consisting of a face configuration made from three black blobs on a white oval; a black T shape on a white oval; three white blobs in facial configuration on a black oval; and a white T-shape on a black oval which were each presented paired with the same image inverted. The participants' task, rather than detecting dot targets as in a traditional dot probe experiment, was to identify a particular letter within a string of letters. Strings of letters were presented in both locations where stimuli had appeared previously, but the target letter only appeared in one of the strings. Therefore, as in a traditional dot probe task, a faster reaction time to identify the target letter when it is in the location of one category of stimuli compared to another reveals an attention bias to those types of stimuli. The face configurations were used as they have been found to elicit rapid orienting of attention in infants therefore suggesting that they are detected via the subcortical face detection route. It was found that both the ASD group and the control group were faster to detect the target when it was displayed where the face configuration had been than at the opposite location, whereas there was no difference between congruent and incongruent trials for the other types of stimuli. Therefore the authors conclude that subcortical orienting to faces is intact in adults with ASD suggesting that individuals with ASD may have an innate propensity to attend to faces, however they suggest that differences in attention to faces may be found in whether faces hold attention. Shah et al. suggest that reduced social motivation may result in reduced voluntary attention to faces and therefore decreased specialisation with faces. However, whilst Shah et al. used schematic faces to replicate orienting to faces found in infants, an effect produced with these stimuli may not translate to real human faces as the schematic stimuli are very simplistic. Rosset et al. (2007) found that children with ASD process cartoon face typically but not photographs of faces. It is possible that simplistic face stimuli are more successful in capturing attention than more complex ones.

However, typical social orienting in children with ASD has also been demonstrated by Fischer et al. (2013) using photographs of faces. Fischer et al. used a gap overlap task with central and peripheral stimuli that were either social (faces) or non-social (fruits, vegetables, trains). Trials where the central stimulus offset prior to the onset of the peripheral stimulus measured orienting to the peripheral stimulus. Both the ASD group and the control group were found to be faster to make a saccade to the peripheral stimulus when it was social rather than non-social. This was taken to be indicative of intact social orienting in ASD. However, the gap overlap task uses rapid onset peripheral stimuli which will therefore exogenously orient attention to them. This means that attention is forced to the social stimuli rather than selectively allocated to them, and it is not clear that faster orienting to social stimuli would occur if the task did not force the perception of the stimulus.

Some research using eye tracking methodology has looked at the time course of attention to people within scenes as a measure of naturalistic orienting attention towards social stimuli. Fletcher-Watson, Leekam, Benson, Frank, and Findlay (2009) measured where participants with ASD and control participants fixated first within a scene that contained a person. The control group had a greater proportion of first fixations on the person compared to the background, whereas participants with ASD were found to have an equal proportion of first fixations on the background around the person as on the person. First fixations in free viewing eye tracking experiments reveal which part of the image participants are drawn to attend to first, and as such provide a naturalistic measure of selective orienting. Therefore, the difference in first fixations to people compared to background between the ASD and control groups is suggestive of a difference in the attentional priority that social information receives during natural viewing of scenes. The control participants were prioritising the people in scenes whereas the ASD group were not differentiating between the person and the background in their allocation of attention. This suggests that social stimuli may be of less salience to the ASD group as they are not prioritised in the initial sweep of attention over the scene. This result is further supported by Riby and Hancock (2009a) who presented participants with images of natural scenes with a face embedded within them in an unnatural place (e.g. over the top of a house). The latency to make a fixation on the face was recorded and it was found that participants with ASD took longer to fixate on the face than the typically developing comparison group. The authors argue that this provides evidence that faces do not capture attention in a typical way in ASD.

However, once again, research on social orienting in ASD using eye tracking first fixations is also mixed. Kuhn, Kourkoulou, and Leekam (2010) found that participants with ASD were slower to make a saccade towards the face whilst watching a magician perform a magic trick than the control group, but also that the ASD group did not fixate the fast moving ball used in the trick. The authors therefore conclude that it is not specifically social attention that is impaired, rather it is a general slowing in the ability to move attention. Other methodologies have revealed that the prioritisation of social information in visual attention in ASD may be typical. Change blindness studies involve the rapid sequential and repeating presentation of two images of one scene where one element of the scene is altered in one of the images. Participants are required to respond when they detect what has changed between the two images. Faster reaction times to respond to changes within a particular category of objects in the scenes is indicative of greater attention to that area relative to others. In a change blindness experiment, New et al. (2010) found that both control participants, and participants with ASD were faster and more accurate to detect changes in scenes to people compared to animals, plants, and inanimate objects. The authors suggest that people with ASD are able to prioritise animate objects over inanimate ones in their attentional allocation, however it is the attention and processing of cues within that category, such as interpreting information from the eyes, which is impaired in ASD.

Additionally, Jones and Klin (2013) found evidence that 2 month old infants later diagnosed with ASD allocate a comparable proportion of attention to the eye region of faces to infants who develop typically whilst viewing videos of an adult interacting with the viewer. However, this attention to eye regions then declines whilst attention to non-social objects increases by 24 months. This initially comparable level of attention to the eye region of faces suggests that the innate subcortical route of social orienting is initially intact in ASD and that differences in the prioritisation of faces in attention occurs further downstream, potentially in cortical regions. Whilst Jones and Klin made an effort for the actor in the videos to be situated in a natural setting which was set up to look like a child’s room with bright colours and toys in view, it appears from the video stills that the actor filled the majority of the screen and these items were behind her, potentially increasing the salience of the person and decreasing the salience of the objects. Therefore whilst this study is important in the analysis of attention within a face in ASD, it does not conclusively indicate that attention would be immediately oriented to the face over other objects.

In summary, research regarding rapid, automatic orienting of attention to social stimuli in ASD is mixed. Very few studies have isolated this particular mechanism of attention specifically. It appears that when attention is guided towards social information, such as the exogenous capture of attention in the gap overlap task used by Fischer et al. (2013) or in the change blindness study of New et al. (2010) where attending to social information is beneficial to the task, social orienting may appear typical in ASD. However, when attention is free to be allocated naturally and is irrelevant to task demands, as in Moore et al. (2012), Riby and Hancock (2009), and Fletcher-Watson et al. (2009), individuals with ASD may not naturally orient attention preferentially to social stimuli over non-social stimuli.

2.2.4.2 Disengaging from Social Stimuli in ASD

As in typical development, there is less research on disengaging attention from social stimuli in ASD than on the initial orienting of attention or an overall proportion of fixation time. However, Shah et al. (2013) point out the importance of exploring whether social information holds attention in ASD as that may be more indicative of top down control of attention and therefore relates to social motivation.

Two studies to date have specifically aimed to investigate the disengagement of attention from social stimuli in ASD. Chawarska, Volkmar, and Klin (2010) tested the disengagement of attention from faces and non-social stimuli in toddlers with ASD. A photograph of a face or a scrambled face photograph was presented in the centre of a screen and the time participants took to make a saccade to a peripheral stimulus was measured. It was found that the toddlers with ASD were quicker to disengage attention from the central face than the developmentally delayed or typically developing control groups. There was no difference in this measure of disengagement between groups for the non-social (scrambled face) stimuli. The authors suggest that the faces hold attention in the control groups because they are driven to process the faces, and link the lack of attentional engagement to faces in the ASD group to reduced cortical specialisation for faces as a result of reduced subcortical face detection (as described in the Face Processing section above). Similarly, Kikuchi et al. (2011) found evidence to suggest disengagement from faces is atypical in ASD. In a gap overlap task, images of faces or houses were used as central stimuli, and peripheral stimuli consisting of non-social spherical objects were presented either whilst the central stimulus remained onscreen, or after a temporal gap from central stimulus offset. It was found that typically developing children were slower to make a saccade to a peripheral stimulus when the central face remained onscreen than when a central house remained on screen, whereas the ASD group did not differ in saccadic reaction times away from these two types of central stimuli. Additionally, the typically developing group were slower than the ASD group to make a saccade to the peripheral stimulus when the central face stimulus remained onscreen, with no group difference when the central stimulus was a house. Kikuchi et al. further investigated disengagement from faces in ASD by manipulating where on the central stimulus attention was engaged. In experiment 2, participants were instructed to fixate on the eye region of the central faces (and equivalent spatial location on houses) and this was supported by the placement of a fixation cross between the eyes of the face. In this condition, both groups were slower to disengage from a central face stimuli than a house, with no group differences across these two types of stimuli. In a third experiment, Kikuchi et al. instructed participants to fixate on the mouth rather than the eyes of the faces. It was found that neither group showed any difference in disengaging attention from the faces or houses in this condition. The authors suggest that attention to eyes is necessary to for delayed disengagement from faces in typical development and ASD. Once again this study supports the notion highlighted in the Social Orienting section above that attention to social information may be atypical in ASD when it is allocated according to volitional control, but when task demands require attention to social information (the eyes in this case), typical social attention can be observed. Taken together, these two studies suggest that faces relative to non-social stimuli are less salient to individuals with ASD and do not hold attention to the same degree as in typical development. However it should be noted that neither of these studies manipulated the type of non-social objects that the faces were presented with, and in Chawarska et al.'s study, the non-social stimulus lacked any meaning as it was simply a mosaic pattern made from the scrambled face images.

The influence on attention of different types of non-social images has been explored by research using a measure of the length of fixations on social and non-social objects using eye tracking. Sasson et al. (2011 and 2013) have identified differences in disengaging attention from these objects in ASD and typical development. Using eye tracking, Sasson, Elison, Turner-Brown, Dichter, and Bodfish (2011) found that participants with ASD fixated for longer on images of non-social objects than social images during free viewing of arrays of social and non-social objects. A similar result was found by Sasson and Touchstone (2013) who measured fixations with eye tracking whilst children with ASD and typically developing controls viewed pairs of images, one of which was a face, and the other a non-social object which was either of 'high autism interest' or 'low autism interest' (see Circumscribed Interests section below for more in depth discussion in relation to these different types of objects). It was found that the ASD group had shorter fixations on the social stimuli when they were paired with the objects of high autism interest. These two studies indicate reduced motivation to maintain fixation on social stimuli in the presence of potentially more interesting non-social stimuli.

Therefore, research is still conflicting in this understudied area, with Chawarska et al. (2011) and Kikuchi et al. (2011) reporting atypical disengagement from faces in ASD, but Sasson et al finding that atypical disengagement from social information only occurred in the presence of objects of circumscribed interest. Additionally, the research described above involved children with ASD, and research investigating the disengagement of adults with ASD from social stimuli has yet to be investigated.

2.2.4.3 General Social Attention in ASD

The priority that social information receives in attention can be measured by experiments which explore the general allocation of attention when viewing stimuli in the visual field. This examines top down allocation of selective attention under volitional control. Eye tracking methodology is best placed to examine this type of attention as it provides a naturalistic marker of where overt attention is allocated when looking at a scene. However, alternative methods have also been used to provide an index of whether social or non-social objects receive general attentional priority in visual attention.

Moore, Reidy, and Heavey (2015) used a Face in the Crowd Task to explore visual attention to social and non-social objects. The task involves identifying a unique target among identical distractors. The stimuli were either faces, cars or houses, and one exemplar of each could appear within a 3x3 arrangement of one of the other types of stimuli. Participants were required to press a key to indicate that an array contained an 'odd one out' or whether they were all the same. Both the participants with ASD and the control participants were faster to identify a target when it was a face, regardless of whether it was presented among cars or houses, than to detect a non-social target. This suggests that for people both with and without ASD, faces capture attention to a greater degree than non-social objects. Moore et al. acknowledge that this finding is contrary to their previous finding of reduced social orienting in ASD using a dot probe task (Moore et al., 2012). The authors suggest that this discrepancy may be a result of task demands. In the dot probe task, the images presented were incidental to completing the task, whereas in the Face in the Crowd experiment, it is necessary to attend to the images and process them to complete the task. As has been suggested earlier in this literature review, it appears that when individuals with ASD are required by task demands to attend to faces, social attention may appear typical, but in experiments where attention is under more volitional control, individuals with ASD tend to show a reduction in attentional preference for social information.

Eye tracking studies offer a more naturalistic investigation of where attention is allocated in ASD over time. In a series of eye tracking experiments investigating visual attention during free viewing, Riby and Hancock found evidence that individuals with ASD spend less time in general looking at faces than typically developing controls. When viewing natural social scenes (e.g. a photo of a bride and groom), adolescents with ASD spent less time fixating the people, and particularly faces, and more time fixating the background, in the scenes than the comparison groups matched on chronological age or non-verbal age (Riby & Hancock, 2008). The authors suggest that reduced attention to faces may have implications for the social functioning of individuals with ASD as they are not looking at faces long enough to interpret or learn how to interpret information from them. Additionally, in the study described earlier using eye tracking to measure fixation behaviour while viewing natural scenes with embedded faces, Riby and Hancock (2009a) found that children and adolescents with ASD were slower to initially fixate the face, and spent less time fixating on the face once they had detected it than the typically developing control group. In another task where a face appeared in a scrambled image of a scene, once again the participants with ASD were slower to fixate the face and spent less time overall fixating on it than the comparison group. The authors link this tendency to reduced social interest in the ASD group. In a third experiment, Riby and Hancock (2009b) found that children and adolescents with ASD spent less time fixating on the faces of characters in movie clips containing cartoon people or human actors than typically developing controls. The authors had hypothesised that the participants with ASD may show typical attention to social information in the scenes when viewing cartoon movies as opposed to acted movies as previous research had found typical viewing behaviour towards faces for cartoon images (Van der Geest, Kemner, Verbaten, & Van Engeland, 2002). However, it was found that attentional atypicalities were present even when there was reduced ecological validity in the scenes.

However, whilst Fletcher-Watson et al. (2009) found differences in orienting to social information in natural scenes in ASD (as described above), it was also found that participants with ASD spent overall as much time fixating on the person as the typically developing control group, suggesting that in this study, social information was as semantically salient to the ASD group as the control group. Similarly, Kuhn et al. (2010) found that participants with ASD spent as much time fixating the face of a magician while he performed a vanishing ball trick as the control group suggesting that individuals with ASD allocate as much visual attention to social information as typically developing controls.

Additionally, whilst Riby and Hancock (2009b) found differences in gaze behaviour to faces in ASD and control participants when viewing cartoon images, Gillespie-Smith, Riby, Hancock, and Doherty-Sneddon (2013) found no difference. Gillespie-Smith et al. used eye tracking to observe the fixation behaviour of children with ASD (mean age 13 years 7 months) when looking at pictures from picture communication systems which are used in school to facilitate communication. They used pictures from two types of communication system which differed in how complex and therefore how realistic they were (both were still cartoon style pictures). The pictures shown to the children were either of people performing actions such as brushing their teeth, or of non-social objects such as cooking utensils. It was found that the children with ASD and the chronological age, non-verbal age, and verbal age matched comparison children all spent more time fixating on the face images than the object images. No group differences were found in relation to fixations on objects either. The authors conclude that when ecological validity of images is low, individuals with ASD may show typical social attention, and that reduced social attention as seen in Riby and Hancock (2008) may be the result of more complex images used. The results of Gillespie-Smith et al. may differ from those of Riby and Hancock (2009b) as the drawings in the communication systems used are even simpler than those used by Riby and Hancock (2009b). Additionally, Gillespie-Smith et al. presented the images in isolation and so there was no wider context or other objects to compete for attention. Whilst Gillespie-Smith et al.'s study highlights the utility of simple pictures in facilitating communication in young people with ASD, it also highlights the need for greater ecological validity if researchers wish to uncover real world looking behaviour in individuals with ASD.

Additionally, Freeth, Chapman, Ropar, and Mitchell (2010) found evidence to suggest that individuals with ASD spend as much time fixating social information within a scene as much as typically developing controls. They explored visual attention to people and gaze direction within natural scenes in adolescents with ASD. It was found that there were no group differences in proportions of fixation time spent within the top or bottom halves of the face when the scenes were viewed for 5 seconds. However, as in Fletcher-Watson et al. (2009), time course analysis revealed that the ASD group were slower to first fixate the face in scenes. The authors suggest that the longer time taken to fixate the face by the ASD group is the result of reduced salience of faces. Freeth et al. (2010) suggest that their results in overall looking time to faces within scenes differ from those of Riby and Hancock (2008), who found reduced fixation time to faces in participants with ASD, are the result of the level of functioning of the participants. The participants in Riby and Hancock's study were lower functioning than those in Freeth et al.'s study, and Freeth et al. suggest that reduced social attention may be linked to developmental delay rather than ASD per se.

Whilst Freeth et al. use naturalistic stimuli to explore gaze behaviour in relation to social information in ASD, it should be noted that their stimuli tend to show one person sitting on a chair and not engaged in any activities. Riby and Hancock (2008) specify that their social scenes include people engaged in natural activities. Therefore these scenes may contain more context than those in Freeth et al. It could be that context is equally as important as the use of photographs instead of cartoons in exploring social attention in ASD. With context removed, it might be easier for individuals with ASD to attend to social information as the complexity of the scene is reduced in the sense that no interpretation of what is occurring is required.

This was explored by Hanley, McPhillips, Mulhern, and Riby (2013). They compared viewing behaviour of adolescents and young adults with ASD with an age, gender and IQ matched control group whilst looking at acted or natural stills from film clips that contained either isolated faces or two people interacting with each other. The aim of the study was to explore attention within faces in relation to ecological validity of the stimuli. It was found that there were no group differences in fixation time to the eyes when faces were viewed in isolation. However, as the ecological validity increased and more than one person was present in a scene, it was found that the ASD group spent significantly less time fixating in the face and eye regions of the scenes than the control group. The authors suggest that looking at the eyes of other people is not aversive for individuals with ASD, as they showed typical eye gaze when faces were presented in isolation, rather they suggest that as the social content of scenes increased, the typically developing participants increased their attention to the eye region whereas the ASD group did not. Birmingham et al. (2008) have previously demonstrated that in typical development, increasing the social content of scenes increases fixation time to the eyes as viewers are driven to understand the interaction between the people in the scenes. Hanley et al. suggest that the participants with ASD in their study did not demonstrate this drive. Alternatively, they suggest that when faces are presented in isolation, attention is forced towards them, whereas when they appear within more complex scenes, there is more competition for attentional resources and faces and eyes do not receive the same priority.

The above studies highlight how differences in task and stimuli can impact on the conclusions that researchers make. Tasks in which attending to a face is intrinsic to task completion tend to find typical attentional preferences for social stimuli in ASD (e.g. Moore et al., 2015, Fischer et al., 2013). However, studies in which attention to faces is incidental to the task produce a more mixed picture. Free viewing studies with simplistic, cartoon stimuli (Gillespie-Smith et al., 2013, Van der Geest et al., 2002, except not Riby & Hancock, 2009b), or with single faces presented in isolation (Hanley et al. 2013) tend to find typical social attention in ASD. However, when more complex stimuli are used, findings are still mixed as to whether individuals with ASD show typical or atypical social attention (e.g. Fletcher Watson et al., 2009 and Freeth et al. (2010) vs Riby & Hancock, 2008). However, some of the studies which present people within social scenes still only present one person in the scene, and the removal of a natural context and meaning to the scene may account for these differences.

2.2.5 Social Attention in the Subclinical spectrum of Autism Traits

There is much less research investigating social attention within the subclinical spectrum of autism traits. However, the reported research to date indicates that differences in social attention may also be evident across the spectrum including below the clinical cut off.
Using eye tracking technology, Freeth et al. (2013) found that autism traits as reported by the AQ, were negatively related to the proportion of time spent fixating an experimenter when the experimenter made eye contact. This was only found to be the case when interaction with the experimenter took place via video and not when interaction was face to face. The authors suggest that this is because when a person is present in the room, the social information is more salient than when presented via video and therefore may enable typical social attention in those with higher levels of autism traits. This shows that subclinical autism traits are related to reduced social attention as those with lower levels of autism traits spent more time fixating the experimenter in the video condition than those with high levels. Bayliss and Tipper (2005) examined the orienting of attention to and from social stimuli in relation to subclinical autism traits as measured by the AQ. Participants were required to respond to a target which could appear on either face or scrambled face stimulus pairs which flanked a central stimulus that was either a face or an arrow cue. It was found that participants with low AQ scores were faster to respond to targets which appeared on face stimuli than scrambled face stimuli, whereas those with high AQ scores were faster to respond to targets on scrambled face stimuli than face stimuli. However, experiment 2 in the same paper revealed that the high AQ scorers also responded faster to targets that were presented on scrambled images of tools relative to whole images of tools, whereas the low AQ scorers showed the opposite pattern. Taken together, these two experiments suggest an attentional preference for non-social, meaningless stimuli in those who score highly on the AQ. The authors suggest that the scrambled objects may contain more detail and appeal to the increased drive to systemise in those with high levels of autism traits (Baron-Cohen et al., 2003). The scrambled images were made up from small square sections of the original image jumbled up and therefore this may be true as it appears there were more lines and therefore more contrast gradients within the scrambled object stimuli. This study therefore suggests that attention to faces may be

disrupted in relation to high levels of subclinical autism traits in comparison to more complex and potentially interesting stimuli. This is in accordance with literature outlined above which suggests that social attention in ASD may be reduced in the presence of potentially interesting non-social stimuli (Sasson & Touchstone, 2013).

Some research also suggests attention within social stimuli may be atypical in relation to subclinical autism traits. Chen and Yoon (2011) measured autism traits with the AQ and fixation time to an actor's face in videos of them discussing a neutral topic. The actor either displayed direct gaze by looking directly into the camera, or averted gaze where they looked off camera. It was found that participants who scored low on the AQ modulated their fixation behaviour to the eyes depending on the gaze direction of the actor, but those scoring high on the AQ did not. The low AQ scorers were found to have longer fixations on the eye region, and to spend a greater proportion of fixation time on the eyes, when the actor exhibited direct gaze than when they exhibited averted gaze, whereas the high AQ scorers showed no difference between the two types of video. The authors suggest that the longer fixations on eye regions in the direct gaze condition in the low AQ group was the result of reciprocity of direct gaze, a form of social mimicry, which was not shown by the high AQ group. Similarly, Elsabbagh, Volein, Csibra, et al. (2009) examined ERPs relating to direct and averted gaze in the BAP. ERPs of infants (mean age 10 months) with a sibling with ASD and infants with no family history of ASD were compared whilst they viewed images of faces displaying either direct or averted gaze. It was found that the ASD siblings had a slower P400 response to direct gaze than control siblings, but there was no difference in latency for the P400 response in relation to the faces with averted gaze. The P400 response is thought to relate to face processing and top down attention in infants, and that this difference relates to neural detection of mutual gaze. This suggests that the processing of direct gaze is slowed in BAP infants relative to control infants.

Swanson and Siller (2014) explored joint attention in relation to subclinical autism traits in adults measured using the BAPQ. Participants viewed a face in the centre of the screen which either looked towards an object appearing in one of the corners of the screen, or away from the object. Eye tracking showed that participants with lower BAPQ scores attended more to the peripheral object when the gaze of the central face was congruent with its position, and more to the face when it was incongruent. Participants scoring high on the aloof subscale of the BAPQ did not modulate their attention to the central stimulus or the peripheral target whether the gaze congruently or incongruently guided attention to the target.

These findings suggest that social attention in the subclinical spectrum may be atypical in a similar way to that seen in people with ASD, with reduced modulation of gaze behaviour in response to social cues. However, there is only a small amount of research in this area and the majority focuses on attention to eye gaze, with no research reported to date exploring general social and non-social attentional preferences in relation to subclinical autism traits.

2.3 Circumscribed interests in ASD

Restricted or repetitive behaviours, interests or activities (RRBI) form half of the diagnostic characteristics of ASD. These may manifest as: Stereotyped or repetitive motor movements, use of objects, or speech; insistence on sameness and inflexible routines or ritualised patterns of behaviour or verbalisation; restricted interests that are abnormal in intensity and focus (e.g. circumscribed or perseverative interests); and abnormal sensory reactivity (American Psychiatric Association, 2013).

Whilst the term 'circumscribed interests' appears in the DSM 5, researchers offer different definitions of the term. Lam, Bodfish, and Piven (2008) use the term circumscribed objects to include "intense, focused hobbies, strong preoccupations with odd topics… and unusually strong attachment to certain objects" (p.1197). Smith et al. (2009) state that an interest is circumscribed if "it is narrowly focused, pervasive, and does not develop as a typical hobby" (p.987). Similarly, Boyd, Conroy, Mancil, Nakao, and Alter (2007) define CIs as "interests or preoccupations of individuals with ASD that become unusual in their intensity and focus" (p.1551). In the present thesis, the term 'objects of circumscribed interests' will follow these definitions and refer to objects that are frequently identified as being of particularly intense and focused interest to people with ASD.

Turner-Brown, Lam, Holtzclaw, Dichter, and Bodfish (2011) suggest that the CIs element of the RRBI domain of ASD may be the most unique to the disorder because of symptom overlap with disorders such as intellectual disabilities and obsessive compulsive disorder (OCD) in the other areas of RRBI. South, Ozonoff, and McMahon (2005) report that CIs demonstrate greater intensity over time, and Klin, Danovitch, Merz, and Volkmar (2007) find that intensity of CIs predicts lower social functioning later in life. Additionally, Klin et al. (2007) found that CIs were highly prevalent in adolescents with ASD, with 75% exhibiting CIs at preschool age, and 88% having CIs at elementary school age. These are found to remain prevalent throughout the life course with 17% of adults with ASD having six or more CIs in one study (Attwood, 2003) and South et al. (2005) reported that the CI domain of RRBIs was found to worsen with age into adolescence as opposed to other domains which were found to abate as the children in their study got older. Additionally, in a study exploring the content of internet forums, it was found that adults with ASD have more special interests relating to a systemising domain, and that they have more special interests than typically developing adults (Jordan & Caldwell-Harris, 2012). Areas of CI may be an outlet where an individual with ASD is able to demonstrate strengths and ability. However, they can also be debilitating in their interference with other aspects of life. Negative impacts of CIs may include difficulties with social interactions because of a preoccupation with one topic and only talking incessantly about that topic (Mercier, Mottron, & Belleville, 2000).

These studies highlight the importance of research focusing on this understudied area of RRBIs in ASD and its potential link to social functioning.

Baron-Cohen and Wheelwright (1999) investigated the nature of intense interests in ASD. It was found that the children with ASD had the greatest proportion of obsessional interests in the area of 'folk physics'. The term folk physics is used by the authors to refer to an intuitive interest in how inanimate objects work and incorporates machines, vehicles, computers, physical systems and spinning objects. This links to Baron-Cohen (2002)'s EMB theory of autism which suggests that people with ASD have a strong preference to look for systems in their environment and a diminished interest in people. Baron-Cohen and Wheelwright (1999)'s study is supported by Turner-Brown et al. (2011) who found that children with ASD prefer more non-social CIs compared to typically developing children and are particularly interested in mechanical elements of their environment. The children with ASD were found to have more interests relating to folk physics than their typically developing counterparts. Additionally, South et al. (2005) explored repetitive behaviour profiles in HFA and AS. Parents were interviewed about CIs in their child with ASD and the most commonly identified areas of interest were Japanese animation, gadgets/devices, dinosaurs, space/physics, and natural disasters. This also supports the work of Baron-Cohen and Wheelwright (1999) as the areas of gadgets/devices and space/physics can be seen to relate to the domain of folk physics which was identified in their study. This is further supported by Attwood (2003) who identified CIs as frequently manifesting in collecting items of a particular category, which can be typical or idiosyncratic. He states that children with AS are interested in the world of objects and machines whereas typically developing children tend to explore the social world as the world of objects and machinery easier to understand than people.

CIs are found to be heritable and to relate to subthreshold autism traits. Lam et al. (2008) identified three factors of RRBI consisting of insistence on sameness, repetitive motor behaviours, and circumscribed interests. Insistence on sameness and CIs were found to be familial in sibling pairs where both have a diagnosis of ASD, shown by significant correlations in levels of this symptom between the two siblings. CIs have also been found to be familial in the BAP. Smith et al. (2009) identified four factors of RRBI in 245 participants with ASD using items relating to RRBI from the ADI. The four factors identified were insistence on sameness, intense preoccupations, repetitive and stereotyped motor behaviours (simple) and repetitive and stereotyped motor behaviours (complex). The intense preoccupations factor is similar to the CIs factor identified in Lam et al. and includes the 'circumscribed interests', 'unusual preoccupations', and 'unusual attachment to objects' ADI items identified as the circumscribed interests factor in Lam et al., as well as the additional item of verbal rituals. Smith et al. describe intense preoccupations as a narrow focus of attention on hobbies or objects which may impair social functioning. As in Lam et al., in sibling pairs where both had a diagnosis of ASD, the factors of insistence on sameness and intense preoccupations were found to be familial. Smith et al. (2009) also explored correlations between the RRBI factors and BAP domains. It was found that intense preoccupations in children with ASD were positively correlated with aloofness and rigidity in their fathers. The authors suggest that the domains of rigidity and aloofness in the BAP represent milder forms of their intense preoccupations domain. Rigidity is likened to narrow interests or hobbies possibly with the exclusion of other activities, objects or people, and strict adherence to certain ways of doing things. Aloofness is linked to a preference for particular interests above social interactions. The fact that intense preoccupations were found to be linked to BAP traits in fathers and not mothers links to the EMB theory (Baron-Cohen, 2002) whereby males tend to exhibit more autism traits than females.

As well as being implicated in the BAP, there is evidence to suggest that CIs are also related to elevated levels of autism traits in the general population. In typically developing children, higher levels of foetal testosterone have been found to be related to higher levels of restricted interests at four years old (Knickmeyer, Baron-Cohen, Raggatt, & Taylor, 2005). Foetal testosterone is associated with sex differences in social cognition, and higher levels of foetal testosterone have been associated with reduced eye contact in 12 month olds (Lutchmaya, Baron-Cohen, & Raggatt, 2002), and higher levels of foetal testosterone were associated with higher parent rated autism traits in children aged 6-10 (Auyeung et al., 2009). This suggests that higher levels of autism traits may be associated with increased likelihood of restricted interests as is seen in those with a diagnosis of ASD.

Whilst CIs are particularly prevalent in individuals with ASD, research also indicates that typically developing children may have particularly intense interests and that these may vary in relation to sex. DeLoache, Simcock, and Macari (2007) surveyed 177 parents and found that a third of children displayed extreme intense interests, which were much more common in boys than girls. The interests shown by boys and girls were in line with gender stereotypes with half of the boys interests reported as vehicles, trains and machines and nearly half the girls' interests reported as clothes, babies and tea-sets. These gender differences in interests support the EMB theory (Baron-Cohen, 2002) in that boys show a preference for items relating to systemising and girls show more social interests relating to empathising.

2.3.1 Motivation and Attention to objects of circumscribed interest in ASD

Circumscribed interests are an important area of study in ASD. As well as being heritable and therefore potentially informing genetic studies, they are also useful in the area of improving social functioning. CIs have been noted to be detrimental to social functioning in ASD as a person may be so preoccupied with their topic of interest that they neglect to pay attention to those around them, or talk about one topic so extensively that peers do not wish to interact with them (Attwood, 2003). However, researchers note that individuals with ASD may be at their most social when talking about their specific topic of interest (Attwood, 2003; Boyd et al., 2007).

Understanding how these interests interact with social functioning is useful in harnessing these natural interests to improve social functioning. For instance, Boyd et al. (2007) demonstrated that three children with PDD-NOS spent more time socially engaging with peers when an item of CI (a toy train from a TV show and a toy dump truck) was present than when a less preferred toy was present, and initiated social interaction with the peer quicker when the item of CI was present. Additionally, CIs can be used to target problem behaviours and improve specific social behaviours. Keeling, Myles, Gagnon, and Simpson (2003) describe how using a child's special interest (Powerpuff Girls in this case) to create 'power cards' with scripts for appropriate social behaviour helped the child to learn sportsmanship by diminishing whining and screaming upon losing a game and exhibiting more socially appropriate behaviours instead. Attwood (2003) points out, from clinical experience, that children with ASD may have more affection for the object of their CI than for other people. The social motivation theory suggests that people with ASD lack motivation to engage with the social world (Chevallier et al., 2012), and Vismara and Lyons (2007) found that the use of objects of CI increase motivation in three children with ASD to initiate joint attention with their care giver. Where social motivation may be lacking, there may be an increase in motivation relating to objects of CI. In Kanner's original description of autism, it was noted that children often ignored the people present in a room and went straight to objects. It seems that certain objects may elicit the level of attention and motivation for engagement in individuals with ASD that is seen in typically developing individuals towards other people.

This assertion is supported by research which has explored the neural mechanisms involved when looking at images relating to CIs. Grelotti et al. (2005) conducted fMRI with an 11 year old boy with ASD and a special interest in the cartoon Digimon. Results were compared with a 17 year old male with ASD but no special interest in Digimon, and a 10 year old typically developing male with an interest in Pokémon (a similar but distinct cartoon from Digimon). Participants viewed pairs of unfamiliar faces, familiar faces, objects, Digimon and masked Digimon and had to indicate whether the two images in the pair were the same or not. In the participant with ASD and a special interest in Digimon, FFA activation was greater for masked and unmasked Digimon than for familiar or unfamiliar faces, or objects. Neither of the comparison subjects showed greater activation to Digimon over objects. The authors suggest the activation in the region of the FFA to Digimon images is the result of result of expertise in Digimon from spending so much time watching and thinking about them. It is suggested that he did not have this expertise for faces. This is similar to the research from Gauthier et al. (1999) which has indicated that FFA activation can occur when viewing objects relating to areas of expertise in typical development. Grelotti et al. (2005) argue that a neurodevelopmental abnormality may lead to a reduction in social motivation in ASD and this in turn causes people with ASD to pay less attention to faces and therefore not develop the typical cortical face specialisation which is instead shown to Digimon in this case as an object of special interest and expertise. This suggests that the brain in ASD might develop to specialise in areas that are of more interest to the individual than faces.

Due to the diminished attention to social information and increased preference for objects of interest to people often seen in ASD, research has investigated whether this preference is manifested in visual attention. Where typically developing individuals allocate the majority of their attention towards other people because they are socially motivated, individuals with ASD may allocate their attention towards objects which they are more interested in. In one of the first studies to explore visual attention to objects of CI in ASD, Sasson, Turner-Brown, Holtzclaw, Lam, and Bodfish (2008) used eye tracking to monitor gaze behaviour in children with ASD and typically developing controls whilst viewing arrays of objects that were either social (people showing happy expressions), low autism interest (items such as clothing and food) or high autism interest (such as trains and electronic devices). It was found that children with ASD were less likely to visually explore social images when they were presented with high autism interest object images. The authors suggest that salient objects capture attention and prevent children with ASD from attending to the social world. To specifically measure whether objects of CI in ASD have a negative impact on attending to social information, Sasson and Touchstone (2013) presented preschool children with ASD with pairs of images consisting of a face and either an object exemplifying a category found to be of CI in ASD, or an object not typically relating to CIs. When images of faces were presented in pairs with an object of CI, children with ASD demonstrated a reduction in visual fixation on the faces. However, fixations to faces were comparable to that of controls when the faces were presented with items not related to CIs. These initial experiments suggest that attention may be preferentially allocated to certain non-social objects in ASD, however this requires exploring in adults and with more ecologically valid stimuli.

2.4 Research Aims

The above literature review highlights the importance of attention to social and non-social objects in the development of social abilities, and the possibility that differences in attention may contribute to the development of autistic symptomology. However, previous research in social attention in ASD is conflicting, and research regarding attention to objects of CI in ASD is just beginning. The present thesis aims to explore attention to social and non-social objects of CI in the autism spectrum, and to examine whether differences in attention to these objects are also represented in the subclinical autism spectrum. The experiments are grounded in Social Motivation and EMB theories of autism, and in Posner’s model of attention. The experiments in this thesis investigate the orienting of attention to examine what rapidly captures attention in relation to the autism spectrum, and disengaging to examine which type of objects hold attention and indicate interest in that object through experimentally controlled reaction time experiments.

As such, the present thesis adds to existent literature by using controlled reaction time experiments not previously used to explore social and non-social attention in the autism spectrum. The use of eye tracking to explore free viewing of scenes containing social and non-social objects of CIs is used to give a more natural indication of the orienting and disengaging functions of attention, as well as a measure of which type of object is preferentially attended overall in the autism spectrum. The eye tracking experiments build on previous literature by using more naturalistic scenes, and exploring attention to both social and non-social objects. Observing results across these experiments elucidates the attentional mechanisms involved in atypical social and non-social attention in ASD, and the conditions under which it may appear typical or atypical. These experiments were completed first by participants from the general population to explore attention in the subclinical autism spectrum, and then by ASD and control groups. This enables exploration of the notion of a continuum of autism traits by exploring whether this also relates to social and non-social attention, and may highlight similarities or differences between those with a clinical diagnosis of ASD and those with high levels of subclinical autism traits. It was hypothesised that adults with ASD and from the general population with high levels of autism traits would show a reduction in social attention relative to control participants and participants with low levels of autism traits, and increased attention to non-social objects relating to CIs.

Chapter 3
Participants

Chapter Abstract: The present thesis comprises of research with participants from the general population measured on their levels of self-report autism traits, and with participants with a diagnosis of ASD compared to a control group. All participants were adults with average to above average IQ. This chapter highlights the choices made with regards to participant characteristics, recruitment and diagnosis verification.

Autism is a heterogeneous disorder (Abrahams & Geschwind, 2008), with symptoms ranging from mild to severe. Additionally autism traits are considered to be represented on a milder spectrum below the clinical threshold (Constantino & Todd, 2005). The present thesis explores visual attention to social and non-social objects in relation to both subthreshold autism traits and to people with a diagnosis of ASD compared to controls. When conducting research with an ASD group, it is important to consider factors such as sex, IQ, age, and symptom severity as they can all impact on findings (Jones & Lord, 2013). The present chapter discusses issues concerning the participants included in the experiments within the current thesis examining attention to social and non-social items.

3.1 Use of Adult Participants

The present thesis included adult participants aged 18 and over, ranging from 18 to 54 years across experiments with a mean age of 26.66 (*SD* = 7.06). Therefore the samples comprised of mostly young adults. As ASD is a developmental disorder, the majority of research focuses on children or infants with, or at risk of, ASD to improve early identification for early intervention to ensure the greatest chance of improving outcomes (Fletcher-Watson et al., 2009). However, whilst this is an important focus of research, there are many individuals who receive a diagnosis as an adult, or who were diagnosed before the development of such early interventions, and adults with ASD still experience many of the same difficulties as children with ASD (Howlin, Goode, Hutton, & Rutter, 2004; Seltzer, Shattuck, Abbeduto, & Greenberg, 2004). Fletcher-Watson et al. (2009) highlight the importance of autism research in adults as it shows the lifelong effects of developmental difficulties in childhood. Magiati, Tay, and Howlin (2014) found that outcomes in the social domain were particularly poor for adults with ASD, and a qualitative study exploring restricted interests in six adults with ASD aged 19 to 52 found that restricted interests on a particular topic were still present, invasive and related to negative impacts on their personal and professional lives (Mercier et al., 2000). Therefore it is possible that attentional differences to social information and objects of CI found in children (Sasson & Touchstone, 2013) may also be present in adults. Additionally, the aging population means the number of adults with ASD will only increase, and Wright, Brooks, DAstous, and Grandin (2013) highlight the need to understand the difficulties that this somewhat neglected group can face.

The relative paucity of social attention research in adults with ASD is illustrated by looking at review papers in this area. In a review of social orienting using eye tracking methodology, only 5 out of 25 studies examined social orienting in adults with ASD (Guillon et al., 2014). Likewise, Sacrey, Armstrong, Bryson, and Zwaigenbaum (2014) reviewed research investigating the disengagement of attention in ASD, including disengagement from social stimuli. Of 37 studies reviewed, only 12 papers utilised an adult ASD group. Additionally, in the limited literature on social attention and attention to objects of CIs in adults with ASD, the findings are mixed (Guillon et al., 2014). For example, Moore et al. (2012) found that adults with ASD do not show an attention orienting bias towards faces with a dot probe task, whereas Shah et al. (2013) found that they did. These contradictory findings highlight the need for additional research in this area to establish whether atypical social attention is present in adults with ASD.

3.2 Subclinical Autism Traits

The studies in Chapters 4, 5 and 6 included samples with people from the general population to measure attention to social and non-social items across the subclinical autism spectrum. Comparing the results from the subclinical autism trait studies to those with the ASD participants establishes whether studies that extrapolate implications from subclinical populations of individuals with high levels of autism traits to individuals with ASD are justified. This helps to validate the use of general population samples measured on autism traits to understand the clinical disorder of ASD (Grinter et al., 2009). Research investigating attention differences in relation to the subclinical autism spectrum also allows for evaluation of the idea that a wider autism spectrum extends below the clinical cut off. If the participants with high levels of autism traits show similar attentional differences to those in the ASD group, but to a lesser degree, this would suggest that the attentional differences found in ASD also lie on a spectrum related to behavioural traits. This would indicate that attentional atypicalities in relation to faces or people and objects of CI are related to autism traits, and greater attentional differences are associated with greater autism symptomology both above and below the clinical cut off. Although the present thesis cannot infer causality between the two, research indicates that atypical social attention may contribute to social difficulties in ASD (Dawson, Webb, Wijsman, et al., 2005; Elsabbagh et al., 2013).

3.2.1 Measures of traits associated with Autism

The present studies used the AQ to measure autism traits in the general population and those with ASD to support diagnostic status. A self-report measure was chosen for ease of administration and its utility in measuring autism traits in those both above and below the clinical threshold for ASD.

The AQ (Baron-Cohen, Wheelwright, Skinner, et al., 2001) was one of the first measures developed to assess the extent to which adults exhibit traits associated with autism. The AQ comprises 50 questions made up from subscales of social skill, attention switching, attention to detail, communication and imagination. However, these subscales were only found to have moderate internal consistency (α's = .63-.77) (Baron-Cohen, Wheelwright, Skinner, et al., 2001). Participants rate the extent to which they agree or disagree with each statement. In its original conception, the AQ was validated with 58 adults with ASD, 174 control participants, 840 Cambridge University students and 16 Mathematics Olympiad winners. The AQ was found to discriminate between those with and without a diagnosis of ASD, with those with ASD scoring significantly higher than participants without ASD. In the ASD group, 80% scored above 32 and only 2% of controls reached this score, therefore Baron-Cohen et al. suggest that this is a suitable cut off to limit the number of false positives and false negatives that would be identified. The inclusion of a clinically relevant cut off in the development of this measure adds to its utility in the present thesis where the AQ was utilised to support diagnoses (see 3.3.2 below). Aside from the validation in the original study, the AQ has been widely validated by independent research. Austin (2005) showed the AQ to have good internal reliability in a sample of 201 undergraduate students (α = .82 for the full scale), but questioned the original five factor structure suggesting a three factor structure was more appropriate. The five AQ subscales were found to have lower internal consistency (α's =.58-.75), and factor analysis revealed the 50 items loaded onto three subscales which Austin suggested represent Social Skills, Details/Patterns, and Communication/Mindreading. Hoekstra, Bartels, Cath, and Boomsma (2008) examined the factor structure, criterion validity and reliability of the Dutch version of the AQ in 961 students, 302 adults from the general population, and 12 participants with an ASD, 12 individuals with OCD, and 12 participants with generalised social anxiety disorder. However it should be noted that in this study the AQ was scored to a maximum of 200 with statement endorsements, from definitely disagree to definitely agree, being scored 1-4. This is different to the traditional dichotomous scoring of 0 or 1 for agree or disagree which results in total scores to a maximum of 50. It was found that the AQ had good internal consistency (α = .81 for the student sample and .71 for the general population sample) and test-retest reliability (r = .78), and was found to discriminate between general population and clinical groups, with participants with ASD scoring significantly higher than the general population sample and the participants with OCD and SAD. Armstrong and Iarocci (2013) found the AQ to have good convergent validity with the well validated parent report measure of autism traits, the Social Responsiveness Scale (SRS), suggesting that it is accurate in its measurement of autism traits. Woodbury-Smith, Robinson, Wheelwright, and Baron-Cohen (2005) further evaluated the use of the AQ as a screening measure for ASD in 100 patients referred to a specialist clinic for assessment for ASD, and again confirmed that the questionnaire has good discriminative validity for ASD as those who received a diagnosis of ASD scored significantly higher than those participants who did not receive a diagnosis. Woodbury-Smith et al. suggest that a threshold score of 26 is useful for screening referrals for ASD assessments as using this cut off was found to correctly classify the greatest number of participants who received a diagnosis of ASD.

Additionally, the AQ has been used in previous research investigating social attention in relation to autism traits (e.g. Bayliss & Tipper, 2006; Chen & Yoon, 2011; Freeth et al., 2013) adding support for its use as a relevant measure when exploring social attention in the present thesis. Together, the aforementioned research highlights that the AQ is a well validated measure of autism traits in both clinical and subclinical populations with good internal consistency, test-retest reliability, and discriminant validity. However, the factor structure of the AQ has been questioned, and internal consistencies within the original five factor model have been found to be low. Therefore subscales of the AQ are not used in analysis in the present thesis.

At the time the research in the present thesis began, there was one other self-report measure of subclinical traits of autism. This was the Broad Autism Phenotype Questionnaire (BAPQ, Hurley et al., 2007). The BAPQ was designed specifically to test the personality and language characteristics associated with autism in relatives of people with ASD, and was validated in development with this population (Hurley et al., 2007). The validation of the BAPQ indicated that the scale had good internal consistency, and the BAPQ was found to be sensitive to detection of the BAP when compared to clinical assessment of the parents of children with ASD (Hurley et al., 2007). The BAPQ consists of 36 items comprising of subscales of social behaviour, communication and stereotyped-repetitive behaviour. Participants are asked to rate how often each statement applies to them on a scale of 1-6 from very rarely to very often. The items were devised to relate to behaviours frequently identified in interviews with the parents of individuals with ASD. The BAP represents the higher end of the sub clinical spectrum of autism traits as there is theorised genetic liability in the relatives of a person with ASD, and relatives of individuals with ASD report a greater number of autism traits than people from the general population (Bishop et al., 2004). Whilst this scale was designed for use in adult populations, its direct aim to quantify phenotypic behaviours in the relatives of individuals with autism means that it is not designed to measure autism traits in a general population without a relative with ASD, nor do its authors advocate using the measure to discriminate an ASD group from typically developing people (Piven & Sasson, 2014). Therefore this scale was not suitable to measure autism traits in the present thesis.

3.2.2 Creating high and low autism trait groups

In the present study, participants from the general population were split into groups based on the level of self-reported autism traits through a median split. A median split classifies those participants who score above the median AQ score as high AQ scorers, or reporting a high level of autism traits, and those scoring below the median as low AQ scorers, or reporting a low level of autism traits, with approximately equal numbers in each group. This is a common method within the anxiety and depression literature (e.g. Derryberry & Reed, 2002; Oquendo et al., 2014; Scheier & Carver, 1977; Waters, Bradley, & Mogg, 2014), and is also beginning to be used in research relating to subclinical autism traits (e.g. Chen & Yoon, 2011; Cox et al., 2015; Hudson, Nijboer, & Jellema, 2012; Skewes, Jegindø, & Gebauer, 2014; Van Boxtel & Lu, 2013).

The median split may result in a loss of power to detect relationships that do exist (Maxwell & Delaney, 1993) as it classifies a participant scoring one point above the median as equal to a participant scoring 20 points above the median thereby missing any relationship that may occur between two such participants. Whilst it is possible to conduct linear analysis with multiple interactions, as would be necessary in the present thesis, an ANOVA remains the simplest method for inclusion of several between and within subject independent variables. Therefore, despite the potential limitation of dichotomising a continuous variable and losing power, a median split was used to create groups of participants with high and low levels of autism traits in experiments with the general population. Additionally, the creation of low and high autism trait groups allows for a comparison of findings with the ASD vs control studies.

3.3 Sex and the Autism Spectrum

Sex was considered as a factor within the analyses for experiments relating to subclinical autism traits in Chapters 4 and 5. The EMB theory of autism (Baron-Cohen, 2002) argues that autism is an expression of an extreme male brain type with a very high drive to systemise and a low drive to empathise. The male brain in typical development is associated with a greater drive to systemise than to empathise. Therefore typically developing males are likely to show a greater expression of traits associated with autism. Typically developing males have been found to demonstrate higher levels of autism traits than females, scoring higher on the AQ (Austin, 2005; Baron-Cohen, Wheelwright, Skinner, et al., 2001; Hoekstra et al., 2008) and Constantino and Todd (2003) found that females scored on average 25% lower on the SRS measure of subthreshold autism traits than males, and a smaller proportion of females reached clinically relevant scores. In the BAP, the BAPQ has identified fathers of a child with autism as more aloof (not desiring social interaction) than mothers (Seidman, Yirmiya, Milshtein, Ebstein, & Levi, 2012). Taken together these studies suggest that males with high levels of sub threshold autism traits may represent the higher end of the subclinical autism spectrum. Additionally, sex differences are found in relation to social attention in typical development. Connellan, Baron-

Cohen, Wheelwright, Batki, and Ahluwalia (2000) found that male infants looked more at a physical mechanical mobile than faces, and females showed the opposite pattern. Similarly, Lutchmaya and Baron-Cohen (2002) found that 12 month old male infants prefer to look at mechanical motion (moving cars) than biological motion, whereas females showed the opposite preference. Therefore including sex as a factor in analyses of chapters involving subclinical samples allowed for differences in attention to social and non-social objects that may be more subtle in those with high levels of autism traits in the general population to be picked up on, as males with high autism traits may be more like individuals with a diagnosis of ASD relative to females with high levels of autism traits.

The sex ratio across high and low autism trait groups in chapters 4 and 5 was approximately equal. This may be surprising as females tend to score lower than males on the AQ (Baron-Cohen, Wheelwright, Skinner, et al., 2001), therefore it might be expected that there would be more females than males with low levels of autism traits, and more males than females with high levels of autism traits. The mean AQ score for males in Chapters 4 and 5 was 17.75 (SD = 6.40) and for females was 16.55 (SD = 6.58). The mean for females is slightly higher than the female mean of 15.4 reported by Baron-Cohen et al. (2001), however a one sample t-test showed that the mean AQ for females in Chapters 4 and 5 does not significantly differ from 15.4, $t(58) = 1.81$, $p = .076$. Therefore the ratio of females and males in the high and low AQ groupings does not seem atypical, and the even distributions of males and females in the high and low AQ groups enables comparisons of attention across both sex and AQ grouping.

Sex was not included as a factor within analyses in the ASD chapters. The EMB theory of ASD would predict that all participants with ASD demonstrate an extreme systemising type brain regardless of sex (Baron-Cohen, 2002, 2009). Additionally, owing to the higher prevalence of ASDs in males relative to females, it was not anticipated that sufficient recruitment of females would be possible to allow for meaningful comparison between the sexes. The ASD group included 14 males and 6 females in Chapters 7 and 8, therefore there were more than twice as many males as females. This is similar to the male to female ratio of 2.69:1 identified by Baker et al. (2014). In Chapter 9, which included a subset of those in Chapters 7 and 8 based on successful eye tracker calibrations or individual time constraints of participants, the sexes were more balanced with 5 females and 8 males. However, as the sample size was small (13 participants with ASD in total), group sizes would be too small to result in meaningful comparison across ASD and Control groups and sex.

3.4 Recruitment

Participants with ASD were recruited through a number of methods aimed at targeting those with higher functioning ASDs. These included using personal contacts, student services at a local university, through contacting supported living institutions for people with high functioning autism/Asperger's, a social group for students with disabilities at the University of Bath, a database of individuals who had previously participated in ASD research elsewhere in the country who were willing to participate in further research, and through advertising on a local support website for people with Asperger's. The use of advertising for participants through support services added support to diagnosis verification as the participants that were recruited through those channels had had their diagnoses checked in order to receive services. Uptake from each recruitment method was generally low, with the most success coming from recruitment at two local universities. This therefore meant that the final ASD sample consisted of individuals with average to above average IQ. As such, the sample may be biased to represent only the highest functioning section of the clinical autism spectrum. However, as discussed below, findings from such a group are likely to translate to those with lower IQs and more severe ASD.

The samples for the subclinical autism trait studies (Chapters 4-6) and the ASD control group (Chapters 7-9) were recruited from the local community through advertising, such as on the University of Bath website. It was not mentioned in the advertisements that the research was investigating ASD. The majority of participants in the typically developing groups either worked or studied at the University of Bath. Again, whilst this may represent typically developing individuals with higher intelligence, this was matched to the ASD group. Inclusion criteria were that the individual had normal or corrected to normal vision, did not have any current psychiatric diagnoses, and were not taking any medication that could affect their cognitive abilities. The ASD Control Group was matched group-wise with the ASD group on chronological age, sex and IQ as each variable can impact on social attention. IQ was measured and matched using the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999), which is a standardised measure of IQ and has been recommended by Mottron (2004).

Control groups comprising individuals with other developmental disorders such as Downs Syndrome (e.g. Baron-Cohen et al., 1985; Landry & Bryson, 2004) or Williams Syndrome (e.g. Riby & Hancock, 2008) are frequently used as a comparison group in ASD research to specifically isolate differences related to ASD rather than developmental delay generally. The decision was made to use a typically developing control group for the present study due to the high functioning nature of the ASD sample which removed the confound of intellectual disability (Williams & Gray, 2013).

3.5 ASD Symptom severity

The present research utilised people diagnosed with ASD with the inclusion criteria of full scale IQ above 70. Full scale, performance, and verbal IQs of the participants with ASD and the control participants were measured with the WASI (Wechsler, 1999). The mean FSIQ in the present ASD sample was 111.21 (*SD* = 9.70), with mean performance IQ of 111.45 (*SD* = 10.07) and verbal IQ of 108.95 (*SD* = 10.07). Therefore the ASD sample in the present thesis had an above average IQ. Not all individuals with ASD have IQs in the typical range, and as discussed in Chapter 1, ASD is a spectrum disorder with individuals with a diagnosis exhibiting different levels of symptom severity, from severe to high functioning. Although no DSM diagnosis of high functioning autism (HFA) exists, the term is informally used to denote individuals with a diagnosis of autism and an IQ above 70 (i.e. without intellectual disability; Ghaziuddin & Mountain-Kimchi, 2004). Severe autism is often equated within the literature as ASD with intellectual disability (Burack & Volkmar, 1992). The DSM IV states that the prevalence of intellectual disabilities, defined as an IQ lower than 70, in those with an ASD is 75% (American Psychiatric Association, 1994), although there is no mention of the prevalence of intellectual disability in those with ASD in the DSM 5.

It is suggested that differences in attention to social and non-social objects found in individuals with ASD relate to those both with HFA and severe ASD. The mean FSIQ for the ASD group in Fletcher-Watson et al. (2009)'s study was found to be lower than the control's so the measures of social attention were tested to establish whether IQ impacted on them. It was found that IQ scores were not related to the eye tracking measures of social attention. Similarly, Klin et al. (2002) found no relationship between verbal IQ scores and measures of fixations on the mouth, eyes, body and objects in movie clips. In addition, differences in social attention have been found in moderate and severe autism (e.g. Riby & Hancock, 2008) and in those with HFA (Fletcher-Watson et al., 2009). This shows that findings from participants with HFA are likely to apply to those with more severe autism. Therefore, findings from the high-functioning samples included in the present ASD samples are likely to translate to those with more severe autism. Furthermore, the present thesis explores specific, time sensitive elements of attention, and the studies used required good motor skills and focused attention. It was required that participants fixate on the screen for the duration of each experiment, which could be up to 20 minutes (including breaks between blocks). Williams and Gray (2013) point out that people with HFA may be better able to complete such tasks than those with severe autism.

3.6 ASD Diagnosis Verification

The inclusion criteria for the studies with ASD samples was a diagnosis of an ASD (encompassing people with a previous diagnosis of AS, PDD-NOS, and autistic disorder). In the experiments within this thesis, autism diagnoses were checked by observing diagnostic reports from trained clinicians of participants with ASD. Whilst maintaining that diagnosis verification with the ADOS or ADI in research is best practice, Jones and Lord (2013) acknowledge that clinician administered diagnoses based on present and historical symptoms are more stable than the administration of an instrument to check diagnoses. All participants in the ASD group had received a diagnosis from a professional clinician according to international diagnostic criteria. Diagnostic reports that were observed from participants demonstrated ASD symptoms throughout the life course with inputs from the participant and in most cases a parent where the diagnosis was given as a child or a partner where given as an adult. Some participants were recruited from specialist services for people with ASD, through a summer school for students with ASD transitioning to university, or through student support services for students with disabilities at educational establishments. Therefore this is indicative that these participants have received a diagnosis that has been verified as entitling them to additional support in light of it.

Additionally, participants all completed the AQ, and the ASD group exhibited mean AQ scores above the originally conceived cut off for clinical relevance of 32 (Baron-Cohen, Wheelwright, Skinner, et al., 2001; group mean = 32.05, SD = 8.55). In the ASD group, AQ scores ranged from 20 to 46, and in the Control group from 5 to 28. Woodbury-Smith et al. (2005) suggest that a total score of 26 on the AQ is acceptable for screening for clinical relevance. It is acknowledged that five participants in the ASD group in the present thesis obtained AQ scores less than 26. However, none of the participants in the ASD group scored below 20 on the AQ which is in line with the findings of both Baron-Cohen, Wheelwright, Skinner, et al. (2001) and Woodbury-Smith et al. (2005) who found that 96.6% and 98.63% of participants respectively scored over 20, and this drops to 94.8% and 94.52% of participants scoring over 26. It is also worth noting that both Baron Cohen et al. and Woodbury Smith et al. had larger participant pools with a diagnosis of ASD than the present study (n = 58 and 73 respectively). As AQ scores are thought to follow a normal distribution within individuals with ASD, it is likely that with more participants the ASD group would have had a smaller percentage of participants scoring below the cut off of 26. Analyses of the dot probe and peripheral cueing studies in chapters 7 and 8 were repeated without the inclusion of the 5 participants who scored below 26 in the ASD group and the results of the ANOVAs were still significant in the same way, further justifying their inclusion.

Within the autism field, diagnoses and symptom severity are typically measured by using either the Autism Diagnostic Interview-Revised (ADI; Lord, Rutter, & Le Couteur, 1994) and/or the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000). These methods are suggested to be the ‘gold standard’ for confirmation of ASD diagnosis in research samples (Jones & Lord, 2013). However, for research purposes it is not always feasible to have the ADOS/ADI included. Whilst this would have been ideal to do in the present thesis, administering the ADOS or ADI is both costly and time consuming. The costs of training the researcher and purchasing ADOS materials were beyond the funding opportunities for the present thesis.

Individuals with ASD frequently receive comorbid psychiatric diagnoses (American Psychiatric Association, 2013), with one study finding that 70% of a sample of 112 adolescents with ASD met criteria for another DSM-IV diagnosis (Simonoff et al., 2008). Therefore, as would be expected, several of the participants with ASD in the present thesis disclosed comorbid diagnoses, including three with Obsessive Compulsive Disorder, two Attention Deficit and

Hyperactivity Disorder, two anxiety, one depression, and one anorexia. These represented six participants out of the 23 initially recruited, and three of these reported two comorbid diagnoses. Two of these participants' data were not included in analyses for reasons stated elsewhere, meaning that four participants with ASD who were included in final analyses self-reported having additional psychiatric diagnoses. This may mean that differences in their attentional patterns were due to their comorbid diagnoses, and, in particular, anxiety disorders may impact on looking behaviour. It should be noted that social anxiety was measured in all chapters and was not found to relate to any dependent variables, therefore it is unlikely that anxiety was affecting the results. To additionally verify these participants' inclusion in the analyses within the present thesis, analyses were run with and without the participants who disclosed comorbid diagnoses and the outcomes of the ANOVAs in chapters 7-9 were not found to differ from what is reported in these chapters. None of the control participants disclosed any psychiatric disorders.

3.7 Sample Size

Sample sizes in ASD research tend to be small owing to the difficulties in recruiting participants from a clinical group. Computing a priori power analyses to determine sample size for the experiments within the present thesis was a difficult process as little research has used similar methodology, and at the time of design and data collection, no paper utilising a dot probe or peripheral cueing methodology to explore social and non-social attention in relation to the autism spectrum had been published. Studies using similar methodology to the dot probe (Garner, Mogg, & Bradley, 2006) and peripheral cueing task (Fox et al., 2001), but investigating anxiety rather than the autism spectrum, were found to produce medium effect sizes, and previous eye tracking research with participants with ASD was found to produce large effect sizes (Riby & Hancock, 2008) (see Appendix 1 for further details).

As a result of these complexities in determining effect sizes from previous research, a priori power analyses to determine sample size were performed in G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) using a conservative estimate of a medium effect size for the dot probe and peripheral cueing studies. For Chapter 4, with 4 groups (male and female, high and low AQ) and 4 measurements (bias scores for faces and cars at 200ms and 500ms), it was determined that a minimum of 36 participants were needed to achieve a power of 0.80 with an alpha level of .05. However, as the use of a median split results in a potential loss of power, more participants were recruited to ensure that an effect that was present was not missed. The final sample size for Chapter 4 was 111. For chapter 5, the same sample size applies as there are also 4 groups (as before) and 4 measurements (validity scores to faces and cars at 100ms and 800ms). Again, the use of a median split meant that more participants were recruited to achieve maximum power. The final sample size for Chapter 5 was 94. For chapter 6, the original design of the study had hoped for an ANOVA analysis with median split using 4 groups (by sex and AQ grouping) and 3 measurements, this gave a sample size of 40. However, recruitment was only possible via the University of Bath Research Participation Scheme by which psychology undergraduate students participate in research for course credit. This was because of a lack of financial resources for incentives to recruit participants from other populations. Therefore the population from which this sample was taken was predominantly female and the decision was made not to compare sexes. Power analysis with 2 groups and 3 measurements suggested a sample size of 28. Again, a larger number of participants were recruited (n = 40) as a subclinical group were used. However, the sample was not as large as for the dot probe and peripheral cueing studies as eye tracking has been more widely used in ASD research, and effect sizes have been found to be large.

For Chapters 7 and 8 with ASD populations, sex was not compared as it was expected that the sample recruited would be predominantly male owing to the typical ratio of males to females with ASD. Therefore power analyses with a medium effect size (f = .25), for two groups with four measurements gives a sample size of 24 for these two studies. For the eye tracking study, a large effect size (f = .4) was entered based on the large effect size found by Riby and Hancock (2008). This revealed a sample size of 12 was required to achieve power of .80. However, recruitment for clinical groups is difficult and effort was made to recruit as many participants as possible for the ASD group. Therefore sample sizes were higher than the minimum suggested by the power analyses.

Chapter 4
Orienting Attention to Social and Mechanical Objects in the Subclinical Autism Spectrum

Chapter Abstract: Atypicalities in social attention are suggested to contribute to social difficulties found in ASD, and some suggest that attentional priority might instead be given to objects of circumscribed interest. Autism traits are thought to lie on a continuum above and below the clinical threshold, along with accompanying social difficulties. Few studies so far have investigated social orienting in relation to subclinical autism traits. The current chapter presents a dot probe experiment measuring attention biases towards faces and non-social objects of circumscribed interest in the subclinical autism spectrum. Males with high and low levels of autism traits were found to attend more to faces than cars when stimuli were displayed for 200ms, however, this bias was above chance level only in the males with low levels of autism traits. Males with high levels of autism traits were found to show a bias towards faces above chance level when faces were presented for 500ms. This pattern was shown to a lesser degree in females compared to males. It is suggested that this reflects diminished automatic orienting to social information in relation to autism traits. There was no evidence to suggest that subclinical autism traits were related to atypical attention orienting to mechanical objects.

Social attention differences are argued by some to impact on the social development of individuals with ASD. It is thought that diminished social motivation in ASD leads to a reduced preference to attend to social information resulting in a lack of cortical specialisation for perceiving faces and consequently impairments in interpreting and responding to the social world (Chevallier et al., 2012). There is some evidence to suggest that people with ASD demonstrate atypical social attention. Eye tracking studies have found that those with ASD spend less time looking at faces in scenes compared to typically developing controls (Riby & Hancock, 2009a), and look less at the eye region of approaching adults compared to control groups (Jones, Carr, & Klin, 2008). Dawson et al. (2004) found that children with ASD turned their head towards the location of social sounds, such as calling the child’s name, less than the control groups. Dawson et al. suggest that differences in attention to social information appear early in life in those with ASD, and may contribute to continued atypical social behaviours.

However, other research indicates that social attention is typical in ASD. McPartland, Webb, Keehn, and Dawson (2011) compared visual attention to human faces, monkey faces, and other geometric configurations in ASD and control groups using eye tracking. It was found that there was no difference across groups in attention to each of the categories of objects, and those with ASD showed typical attentional patterns to faces, fixating more in the eye region than the mouth region. Similarly, Van der Geest, Kemner, Verbaten, et al. (2002) found that those with

ASD exhibit similar fixation behaviour with regards to face stimuli compared to controls when looking at cartoon drawings. Shah et al. (2013) found intact attention orienting to face like stimuli in adults with ASD using a novel version of a dot probe experiment. Both adults with ASD and typically developing controls were faster to identify targets when shown in place of the face like configuration compared to non-face configurations indicating attention orienting biases to faces in both groups. The inconsistencies in research findings in this area have led some to question the veracity of the social orienting hypothesis, suggesting there is sufficient evidence to indicate typical automatic social orienting in both infants and adults with ASD (Johnson, 2014). Johnson suggests that differences in social behaviours may stem from abnormalities in cortical areas rather than the innate mechanism to attend to faces. However, one of the studies cited by Johnson (Jones & Klin, 2013) explored attention patterns within a face and did not explore selective attention orienting to faces compared to other objects. Therefore, whilst infants who later develop autism may demonstrate typical, subcortical driven attention within faces, it remains questionable whether they would still selectively orient to faces in the presence of other objects, which is the focus of the present study.

Only a small amount of research has focused on social attention in subclinical autism traits. In the general population, autism traits have also been found to be negatively related to attention to social cues. Bayliss and Tipper (2005) found that higher scores on the AQ were associated with a reduction in attention bias to targets that appeared on a peripheral face in a central cueing task. In addition, Freeth et al. (2013) measured autism traits and their relation to fixation time on a conversation partner who was either present in the room or talking to the participant via video. It was found that an increase in autism traits as measured by the AQ was related to a decrease in looking time to the experimenter in an interview when this was conducted via video. The authors suggest that this may be because faces are less interesting to people with high levels of autism traits, but that this is overcome in the live condition when social cues are stronger. Similarly, Chen and Yoon (2011) found that participants who scored highly on the AQ spent less time fixating on the eye region of faces than participants with low AQ scores whilst viewing a video where the actor displayed direct gaze. Participants with low AQ scores spent more time fixating the eye region of faces when the actor displayed direct gaze compared to averted gaze. Additionally, direct gaze was found to elicit longer fixations from the participants with low AQ scores compared to averted gaze. For the participants with high AQ scores, there was no difference in fixation behaviour between the averted or direct gaze conditions. This suggests that participants with high levels of autism traits are less affected by social cues in their allocation of attention as direct gaze tends to elicit gaze reciprocity. Rhodes, Jeffery, Taylor, and Ewing (2013) found males with high levels of autism traits showed poorer identification of faces on a face matching task and reduced adaptation aftereffects in a face identity adaption experiment. This suggests atypical neural face processing in the subclinical autism spectrum. These studies show that high levels of autism traits are related to social attention atypicalities in terms of eye contact and face identification ability. However, no studies to date were identified that directly explored attention to social versus non-social information in the subclinical autism spectrum.

In addition to a suggested reduction in social attention in ASD, there has also been a recent surge of research interest in attention to objects which may be of particular interest to individuals with ASD. This follows from research which has looked at CIs as a subset of repetitive behaviours in ASD (Turner, 1999). South et al. (2005) explored the content of CIs in ASD and identified some common examples such as Japanese animation, gadgets/devices, and dinosaurs. Meanwhile, Turner-Brown et al. (2011) also explored circumscribed interests in children with ASD and found that they differed from control children in the impairment that these interests caused in their lives. Additionally, control children showed more interests in social areas, and those with ASD had more interests in non-social, and in particular, mechanical subjects.

Caldwell-Harris and Jordan (2014) argue for a continuum of special interests from typically developing individuals to those with ASD. Participants who identified themselves as having an ASD and participants who identified themselves as neurotypical completed online questionnaires relating to systemising and theory of mind. They also completed a measure of intense interests. The males with ASD were found to have more interests relating to systemising domains such as vehicles and machines compared to females with ASD, and to male and female neurotypicals. When combined across ASD and neurotypical participants, systemising scores were found to be related to special interests in systemising domains. Systemising scores were also correlated with the average intensity of the participants’ special interests. The authors suggest that, just as systemising traits are distributed continuously throughout the general population and those with ASD, special interests also fall on this continuum. Whilst systemising is not a direct measure of autism traits, it is found to be highly related to autism traits as measured by the AQ, and individuals with ASD demonstrate higher systemising tendencies than typically developing individuals (Baron-Cohen et al., 2003). The idea of a spectrum of interests in non-social domains below the clinical ASD threshold is also supported by Singleton, Ashwin, and Brosnan (2014) who found that participants from the general population with higher AQ scores demonstrated greater skin conductance response, a measure of emotional arousal, when viewing non-social images compared to social images relative to those with lower AQ scores. This indicates that those with higher levels of autism traits below the clinical threshold are also related to atypical interest in the non-social world.

Visual attention has not been measured in relation to non-social objects of circumscribed interest in relation to sub clinical autism traits. However, evidence is emerging that those with ASD may allocate more attention to objects of circumscribed interest than typically developing individuals. Sasson et al. (2008) presented participants with image arrays including social images, and images of items identified as being of circumscribed interest in ASD. It was found that children with ASD explored fewer social images when they were presented among objects of circumscribed interest. Sasson and Touchstone (2013) found that children with ASD attended less to faces than controls only when the faces were paired with objects related to circumscribed interests in ASD, suggesting that objects of circumscribed interest may defer attention away from social information. These findings, coupled with the aforementioned studies indicating a continuum of interests in systemising domains relating to autism traits, suggests that visual attention may also be biased towards objects of circumscribed interests in the subclinical autism spectrum.

Differences in attention to social information are also found across sex. In a central cueing task where a central face indicates the location of a cue by averting its eye gaze to the left or right, males have been found to show a smaller gaze cueing effect than females. Females were found to be faster than males to attend a stimulus that was correctly cued by the face (Alwall, Johansson, & Hansen, 2010; Bayliss, di Pellegrino, & Tipper, 2005). Male neonates have been found to look longer at a mechanical object than a social object with female neonates showing the opposite preference (Connellan et al., 2000), and 12 month old female infants showed a greater looking preference towards faces than male infants (Lutchmaya & Baron-Cohen, 2002). The EMB theory of autism suggests that people with ASD are characterised by extremely high levels of systemising and low levels of empathising, a pattern seen to a lesser degree in males in the general population (Baron-Cohen, 2002). In the general population, circumscribed interests are also found to a greater degree in boys than in girls, and boys interests tend to relate more to systemising domains with girls interests relating more to social domains (DeLoache et al., 2007). Add to this that males tend to possess more autism traits than females (Baron-Cohen, Wheelwright, Skinner, et al., 2001), and it becomes apparent that sex should be considered when looking at social and non-social attention differences in relation to autism traits.

A further aspect of interest in relation to social attention is social anxiety. ASDs are frequently comorbid with social anxiety (e.g. Kuusikko et al., 2008; White, Bray, & Ollendick, 2012), and AQ scores have been found to positively correlate with scores on a social anxiety measure (White, Ollendick, & Bray, 2011). In dot probe tasks, those with high levels of social anxiety have been found to orient attention to faces over other objects to a greater degree than those with low social anxiety (Garner et al., 2006), and other research suggests that people with social anxiety direct their attention away from faces (Chen, Ehlers, Clark, & Mansell, 2002). Therefore social anxiety was measured to establish whether it was impacting on attention biases.

Dot probe tasks have previously been used to demonstrate attention biases towards faces over other objects in the typically developing population. A dot probe experiment investigates the selective orienting of attention, that is, what immediately draws attention in the visual field. Bindemann et al. (2007) found that faces elicit an attentional bias over non-social objects in adults from the general population. Additionally, dot probe experiments are frequently used to investigate the attentional biases that may contribute to anxiety (e.g. Mogg et al., 2000), phobias (e.g. Mogg & Bradley, 2006) and addictions (e.g. Ehrman et al., 2002). Attentional biases towards threatening stimuli in anxiety, for example, are theorised to contribute towards the maintenance of the disorder. Similarly, a lack of an attentional bias towards the social world may contribute to the social difficulties associated with ASD. In the only study which has compared social and non-social attention biases in ASD with a dot probe task, a bias towards social images was not found. Moore et al. (2012) paired face, car and house stimuli in a dot probe task to explore orienting to faces in ASD, and found that those with ASD did not show an attention bias to faces when images were displayed for 200ms, whereas controls did. The results from this study suggest a reduction in automatic orienting of attention to faces in ASD, possibly as a result of diminished social interest in those with ASD, consistent with the Social Motivation theory of ASD (Chevallier et al., 2012).

The present study used a dot probe task similar to that of Moore et al. (2012) to explore attention biases to faces and cars. Images of faces and cars were presented with images of houses as a neutral comparison object in the present study. Pairing the faces and cars together (as in Moore et al., 2012) would have meant it was not possible to determine if a bias was driven by participants avoiding one stimulus, or orienting toward the other. Much of the research investigating circumscribed interests has focused on children, and several of the topics identified as being commonly of particular interest to ASD participants seem less likely to persist into adulthood, such as Pokémon (South et al., 2005; Turner-Brown et al., 2011) and Power Rangers/Ninja Turtles (South et al., 2005). However, some areas such as an interest in mechanical objects, gadgets or vehicles (Baron-Cohen & Wheelwright, 1999; South et al., 2005; Turner-Brown et al., 2011), which also links to the theorised preference for closed systems in ASD (Baron-Cohen, 2002), may be more likely to persist. Car images were chosen to represent a "mechanical" category of objects due to their similarity, from a front view, to faces in terms of the configuration of features (e.g. headlights roughly correspond to eyes, a front grill to a mouth). This selection is in line with other research which has used similar types of stimulus to explore attention to non-social objects which may be of more interest to people with ASD (e.g. Sasson et al., 2008; Parish-Morris et al., 2013; Fischer et al., 2013). Houses have frequently been used as non-social comparison objects to faces, with no evidence to suggest that houses would atypically influence attention in ASD (e.g. Bird, Catmur, Silani, Frith, & Frith, 2006; Kleinhans et al., 2008). Additionally houses have configural similarity to cars and faces (windows corresponding to eyes and headlights) and relative neutrality in that they are neither social nor do they relate to objects of circumscribed interest in ASD.

Dot probe studies investigate the selective orienting of attention. Orienting attention is defined as the aligning of attention with an object in the visual environment (Posner, 1980). Attempts were made in the selection and creation of stimuli to minimise bottom up influences on attention by choosing categories of stimuli that are configurally similar to one another, eliminating colour from images, and matching for luminosity. Therefore an attention bias towards a particular category of stimuli would be the result of top down guided attention indicating that the object is particularly salient to the participant. Top down influences on attention reflect the salience of objects to the observer in terms of reward, threat, learned importance, and current goals (Awh et al., 2012; Desimone & Duncan, 1995). There were no goal directed demands of the current study and attending to one particular category of stimuli was not beneficial for task performance as targets appeared with equal probability in the place of each category of stimulus. Although threat cannot be ruled out as an influence on attentional biases, the measurement of social anxiety aims to account for this potential factor. If higher social anxiety scores are related to greater attentional bias scores then it can be interpreted as evidence of a bias towards threatening information (as in Garner et al., 2006). Therefore, if social anxiety scores are not related to attention biases to faces, it is likely that any such bias is the result of increased importance of that stimulus category as a result of reward value or learned importance to the individual.

In dot probe tasks, stimuli are often presented for 200ms (e.g. as in Moore et al., 2012) and this is considered to capture rapid initial orienting of attention (Mogg & Bradley, 2006). Whilst this attention bias measure is rapid, it is sufficient for face processing to occur, as this can take as little as 100ms (Crouzet et al., 2010). However, in ASD, face processing may not be as automatic as in typical development due to increased feature based processing rather than configural (Lahaie et al., 2006). If face processing is not automatic in ASD, it may take longer for attention biases to faces to be demonstrated. Top down processing occurs more slowly than the automatic configural detection of faces seen in typical development (Hickey, van Zoest, & Theeuwes, 2010), and it is suggested that presentations of 500ms are sufficient to capture this slower, voluntary top down orienting (Müller & Rabbitt, 1989). If participants with high levels of autism traits process faces in a slower and less automatic way, but are still drawn towards them, an attentional bias would be expected to develop when stimuli are presented for 500ms rather than 200ms. Alternatively, if faces are neither processed automatically, nor deemed salient to the individual and therefore eliciting a delayed orienting towards them, then an attention bias will be seen at neither 200ms nor 500ms. If there are attention biases towards a particular category of stimuli at both 200ms and 500ms, this suggests that attention is oriented to them rapidly and automatically, and that it is held there.

There has been some evidence to suggest that the orienting of attention is slowed in individuals with ASD (Townsend, Courchesne, & Egaas, 1996), but this is contested (Iarocci & Burack, 2004). This could result in attention biases being found at 500ms in the high autism trait group instead of at 200ms as it could take these participants extra time to shift their attention. To eliminate this potential confound, raw reaction time scores were compared across groups to assess whether the high autism trait group was indeed slower to allocate their attention.

The aim of this experiment was to investigate differences in the orienting of attention to faces and mechanical objects in individuals from the general population with a high versus low degree of autism traits. It was hypothesised that faces would capture attention more than cars overall as shown by shorter reaction times to detect probes when shown in the location of face stimuli compared to the location of car stimuli. It was further hypothesised that participants with high levels of autism traits would show reduced attention to faces compared to participants with low degrees of autism traits, and that this would vary across the two stimulus presentations in light of research which suggests slowed orienting and atypical face processing in ASD (Behrmann et al., 2006; Dawson, Webb, & McPartland, 2005; Townsend, Courchesne, et al., 1996). It was also hypothesised that those with high levels of autism traits would show a greater attentional bias than those with low degree of autism traits to the mechanical stimuli. Based on the EMB theory and research around sex differences in social attention, it was expected that the group differences would be more evident in males than females.

Method

Participants

The study was completed by 114 people (mean age of 26.47 (SD = 6.95) from the University of Bath (53 males, 61 females) in exchange for £10. Of these 53 (46.5%) were undergraduate or postgraduate students, with the remaining 61 participants (53.5%) holding various positions around the University of Bath, such as research, administration, technical, fundraising or teaching positions. Seventy eight participants identified themselves as white European, 18 as Chinese, 4 as Indian, 3 as white and Asian, 2 as Pakistani, and 1 participant identified themselves as each of the following: Other Asian, Australian, Caribbean, Japanese, Middle Eastern, Other White, Persian, White American, and White and Black.

Participants all had normal or corrected to normal vision, were not taking any medication that affected their cognitive abilities, and did not report having any current psychiatric diagnoses.

Participants were split into two groups based on their AQ score using a median split. Those with scores below the AQ median of 17 formed the ‘Low AQ’ group and those with scores at the median or above formed the ‘High AQ’ group. Descriptive statistics for these groupings are shown in table 4.1. The high and low AQ groups did not significantly differ in mean age, $t(106) = 1.34$, $p = .183$, or in the proportion of males and females, $\chi^2(1, N = 111) = 0.45$, $p = .502$. The high AQ group had significantly higher AQ scores than the low AQ group, $t(106) = -13.63$, $p < .001$, and higher LSAS scores than the low AQ group, $t(106) = -4.19$, $p < .001$.

Table 4.1

Mean (SD) questionnaire scores and demographic information for Low and High AQ groups

	Low AQ (N = 55)	High AQ (N = 56)	Overall (N = 111)
Sex ratio (Males: Females)	24: 31	28: 28	52:59
Mean Age	27.58 (7.91)	25.71 (5.94)	26.59 (6.97)
AQ score**	12.15 (3.32)	22.36 (4.52)	17.28 (6.48)
LSAS score**	33.56 (16.76)	48.29 (18.02)	40.45 (19.12)

** $p < .001$ for difference between groups.

Note: AQ = Autism Spectrum Quotient (maximum score 50); LSAS = Leibowitz Social Anxiety Scale (maximum score 144)

Materials

The AQ (Baron-Cohen, Wheelwright, Skinner, et al., 2001) was used to assess the extent to which participants displayed autism-related traits. The AQ is a 50 item self-report measure of traits associated with autism and participants respond whether they Definitely Agree, Slightly Agree, Slightly Disagree, or Definitely Disagree to items about themselves, e.g. "I prefer to do things with others than on my own". The items are made up of five subscales covering Social Skill, Attention Switching, Attention to Detail, Communication and Imagination. Items where participants Definitely Agree or Slightly Agree are coded 1 for 25 items and Slightly Disagree and Definitely Disagree are coded 0 for those items. The scoring is reversed for the remaining 25 items. Scores are totalled out of a maximum of 50. Higher scores indicate greater levels of traits associated with autism.

The self-report Leibowitz social anxiety scale (LSAS; Baker, Heinrichs, Kim, & Hofmann, 2002) was administered to investigate whether social anxiety was related to orienting to faces. This is a self-report version of the Leibowitz Social Anxiety Scale that was originally developed for clinician administration (Liebowitz, 1987). The self-report version has been shown to perform as well as the clinician administered version of the LSAS (Fresco et al., 2001) and Baker et al. (2002) found the self-report version to have good internal consistency, test-retest reliability and convergent and discriminant validity. This measure presents 24 social situations (e.g. "Going to a party") covering social interactions and performance situations which the participant has to respond how much they fear that situation from 0 (no fear) to 3 (severe fear), and how much they avoid that situation from 0 (never) to 3 (usually). This results in two subscales of Fear and Avoid which make up the total LSAS score. Total scores can range from 0 to 144.

Stimuli

Sixteen face stimuli (eight male and eight female) with neutral expressions were taken from the Karolinska directed emotional face stimuli (KDEF; Lundqvist, Flykt, & Öhman, 1998). The KDEF stimuli are a well validated set of face stimuli displaying emotional and neutral faces created for use in experiments (Goeleven, De Raedt, Leyman, & Verschuere, 2008). Sixteen car stimuli were produced by cropping front images of cars taken from public domain websites. Thirty-two images of houses were also downloaded from public domain websites, and were used as the neutral stimuli. Using PaintShop Pro, images were cropped to approximately fill a square of uniform size (see Figure 1) and set to greyscale. A pale grey colour was used as the background colour and to crop the edges of stimuli to eliminate any extraneous features to minimise differences in shapes of stimuli (e.g. hair and ears on faces, wing mirrors on cars, extremely dark patches on houses). Luminance was adjusted on all stimuli to create an average luminance for each stimulus group (faces, cars and houses) of 81 cd/m^2 as measured by PaintShop Pro (See figure 4.1 for an example of each type of stimulus).

Figure 4.1. Examples of a) face stimuli, b) car stimuli and c) house stimuli

All stimuli were rated by 22 people (11 males, 11 females; mean age 29.64, *SD* = 7.26) on interest, complexity and valence (positive/negative) using a Likert scale of 1-5, with one indicating very uninteresting/simple/negative, three being neutral, and five indicating very interesting/complex/positive (see Table 4.2 for mean ratings).

Table 4.2

Mean rating scores for each stimulus type (SD)

	Faces	Cars	Houses
Interest	2.69 (0.63)	2.36 (0.63)	2.76 (0.42)
Complexity	2.84 (0.66)	2.52 (0.60)	3.15 (0.54)
Valence	2.71 (0.37)	2.79 (0.45)	3.00 (0.33)

Paired samples t-tests were used to compare mean ratings for each type of stimulus across the three measures. As this resulted in 9 comparisons, a Bonferonni Correction was applied to the alpha level of .05 to give an alpha level of .006.

Valence

There were no differences between faces and cars in terms of valence, $t(21) = -0.69$, $p = .499$, or between houses and cars, $t(21) = -2.34$, $p = .029$. Houses were rated more positive than faces, $t(21) = -3.17$, $p = .005$.

Complexity

There was no significant difference in the ratings of complexity between faces and cars, $t(21) = 1.95$, $p = .064$, or between faces and houses, $t(21) = -1.73$, $p = .099$. However houses were rated significantly more complex than cars, $t(21) = -4.34$, $p < .001$.

Interest

No significant differences were found between ratings of interest for faces and cars, $t(21) = 1.78$, $p = .090$, or between faces and houses, $t(21) = -0.50$, $p = .621$. Houses were rated significantly more interesting than cars, $t(21) = -3.51$, $p = .002$.

Procedure

Responses in dot probe tasks can involve responding only if a target is present (probe detection); responding to indicate the side of the screen a probe appeared on (probe location); or responding as to the type of target displayed (usually .. or :; probe discrimination) There are limitations from a probe detection design in that not every trial elicits data as only trials where the probe was present are included (Bradley, Mogg, Falla, & Hamilton, 1998). This means a greater number of trials are needed resulting in lengthy testing procedures. Probe location designs leave the experiment open to participants choosing only to attend one side of the screen (Bradley et al., 1998) meaning that participants are not necessarily open to attending to both stimuli that are presented. Probe discrimination ensures that the participant attends to the location of the probe in order to make the judgement as to what type of target is displayed. Although it is acknowledged that probe location trials may produce fewer errors and faster reaction times (Mogg & Bradley, 1999), a probe detection method was selected as the benefit of ensuring the target location is attended to outweighs the negatives.

Participants completed the dot probe task using E-prime on Intel Core 2 stone computers in a quiet lab at the University of Bath. Participants sat approximately 57cm from the screen. At the beginning of each trial, a central fixation cross was presented for 500ms followed by each stimulus pair for 200 or 500ms. The display on each trial consisted of a house paired with either a face or a car. Each picture subtended a visual angle of 6° and the centre of each picture was 9° from the centre of the screen, with one always to the left of centre and one to the right. Each stimulus was 7.2cm wide by 9.6cm in height. Immediately after presentation of the picture stimuli ended, a probe of either two horizontally aligned dots (..) or two vertically aligned dots (:) was displayed in the centre of where either the left or right image appeared until either a response was made or to a maximum of 2000ms (see figure 4.2). After an inter-trial interval of 500ms the next trial began.

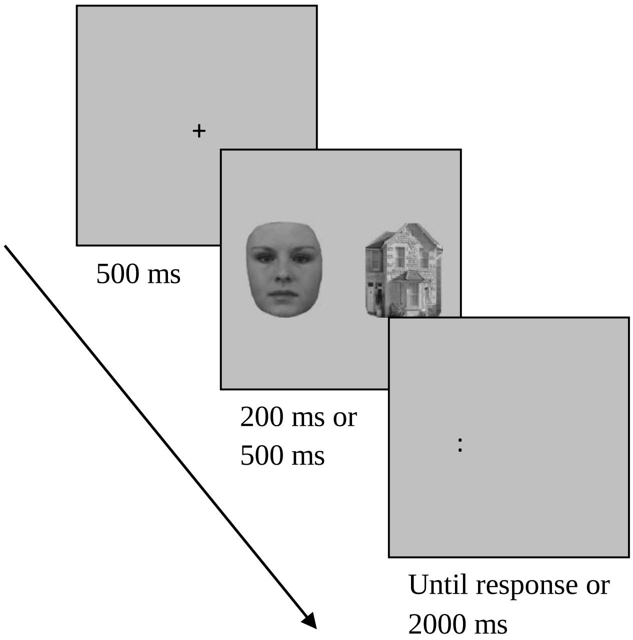


Figure 4.2. An example of a face congruent experimental trial. A central crosshair was presented for 500ms, followed by presentation of car/face-house pairs for 200 or 500ms. The dot target is then presented in place of one stimulus until response to a maximum of 2000ms.

A practise session of 16 trials using images from the experiment was initially completed to ensure participants understood the task. The 256 experimental trials were then completed in four blocks of 64. Participants had the opportunity to take a moment's break in between blocks. There were 128 each of face-house and car-house trials. Stimuli and targets appeared on either side of the screen with equal probability. The dot target was shown in the location where the face/car had been, i.e. it was face/car congruent, 50% of the time. There were 64 trials each of face congruent, face incongruent, car congruent and car incongruent. For half of each of these (32 face congruent, 32 car congruent), the images were displayed for 200ms. For the other half, the images were displayed for 500ms. The vertical dots (:) were used in 128 trials and the horizontal dots (..) in the remaining 128. Trials appeared in a random order. Participants pressed a corresponding button on the keyboard to indicate the type of probe (.. or :) that was presented as soon as they identified it. Participants pressed the up arrow to correspond to the vertically aligned dots and the right arrow to correspond to the horizontally aligned dots. A sticker showing vertically aligned dots and one showing horizontally aligned dots were placed on the corresponding keys. These keys were chosen due to their configural similarity to the targets and their proximity to each other to minimise any Simon effects. However it is acknowledged that Simon effects were not controlled for in the present study and should be considered in future research. Participants responded with their dominant hand. If the participant was left handed, the keyboard was moved so the arrow keys were easily accessible with the left hand. Reaction times and accuracy were recorded using the E-Prime programme. Half the participants completed the AQ and LSAS in a randomised order before the dot probe task and the other half completed them after. Questionnaires were completed on a computer in the lab using Bristol Online Surveys which recorded responses.

Results

Data Preparation

Trials with an incorrect response were excluded from analyses to ensure that only responses where visual attention was allocated to the target location were included. Additionally, trials with reaction times less than 200ms were removed as anticipatory (Whelan, 2008), and trials with reaction times outside the range of 2.5 standard deviations either side of the participant's mean were removed (Cooper & Langton, 2006; Fox et al., 2001). Latencies over this time are likely indicative of distraction/lapse of attention which is inevitable in reaction time experiments (Ratcliff, 1993; Whelan, 2008). This method of removing individual outlying reaction times is preferred over an absolute cut off as it retains power in analyses which would otherwise be lost by a skewed distribution impacting on the participant's mean reaction time, and avoids removing real data from slower participants (Ratcliff, 1993). Three participants were excluded from analyses as their number of erroneous trials and trials with outlying reaction times were greater than 2.5 standard deviations from the mean percentage of data discarded for the whole participant pool (16.41%, 15.23% and 10.94%; Cooper & Langton, 2006), therefore it was unclear they were paying sufficient attention to the task. For the remaining 111 participants, errors accounted for 2.63% of data. There was no significant difference between High and Low AQ groups in the mean number of trials discarded due to errors, $t(109) = -0.20$, $p = .844$ (means 6.68 and 6.51 trials per participant, respectively). Trials excluded for being anticipatory or beyond 2.5 SD above the mean reaction time accounted for 2.27% of data. The mean number of trials discarded for this reason did not differ between the High and Low AQ groups, $t(109) = -0.29$, $p = .772$ (means 5.88 and 5.76 trials per participant, respectively).

To eliminate the possibility that attention biases shown at the longer presentation duration of 500ms were the result of slower orienting of attention in those with higher AQ scores, the relationship between AQ scores and mean reaction times across all types of trials was explored. It was found that AQ scores were not significantly correlated with mean reaction times across all participants, $r(111) = -.17$, $p = .07$. There was also no significant difference in mean reaction times across low and high autism trait groups, $t(109) = 1.41$, $p = .16$.

An Attention Bias score was created in order to simplify the reaction time data across stimulus location and probe location as is standard procedure in dot probe tasks (Bradley et al., 1998; MacLeod & Mathews, 1988; Moore et al., 2012). This not only simplifies analysis but also importantly provides an index of whether participants were faster to detect the target if presented in the location of the stimulus category of interest or at the opposite location. This was calculated by taking reaction times for face/car congruent trials, and subtracting them from reaction times to face/car incongruent trials. This produced an Attention Bias score for each stimulus condition at each presentation duration. A positive Attention Bias Score indicates a bias towards that stimulus condition, with higher numbers indicating a greater bias. A negative number indicates a bias away from that stimulus condition, or towards the neutral item, houses. See Table 4.3 for attention bias scores, and Appendix II for raw reaction time data.

The Attention Bias scores for the 4 different conditions in the experiment (faces at 200ms, faces at 500ms, cars at 200ms and cars at 500ms) were tested for normality as parametric tests were to be conducted. Observation of histograms and Q-Q plots suggest that all four variables were approximately normally distributed, with Car Bias scores at 200ms being slightly positively skewed due to longer bias scores to the right of the distribution. The Shapiro Wilk test for normality confirmed that attention bias scores to cars at 200ms violated the assumption of normality, $W(111) = .957$, $p = .001$. The data for the remaining three variables was not found to significantly differ from normality, all W's > .98, all p's > .10. Exploring the car bias scores at 200ms with Z scores found that two participants had absolute Z scores greater than 3.29 suggesting they were outlying values (Field, 2013) which are likely influencing the spread of scores. The main analysis was performed on the data with the outliers removed to establish whether these data points were influential, and the results were not found to alter (see Appendix II). Additionally, Schmider, Ziegler, Danay, Beyer, and Bühner (2010) suggest that ANOVAs are robust to violations of normality, and so analyses were carried out as planned retaining the outlying data.

Table 4.3

Mean (SD) Bias Scores split by sex and AQ Group

	Males		Females	
Type of Bias Score	Low AQ (*n* = 24) Mean AQ = 11.96	High AQ (*n* = 28) Mean AQ = 22.54	Low AQ (*n* = 31) Mean AQ = 12.23	High AQ (*n* = 28) Mean AQ = 22.18
200ms Face Bias	23.61 (26.73)	11.54 (23.58)	23.77 (33.50)	12.09 (31.16)
200ms Car Bias	-2.92 (25.48)	-1.10 (26.18)	6.32 (26.87)	-3.20 (25.36)
500ms Face Bias	15.89 (40.50)	23.81 (26.94)	28.52 (27.34)	18.92 (25.74)
500ms Car Bias	10.71 (19.28)	-0.57 (22.16)	0.36 (29.43)	8.42 (23.91)

Social Anxiety

Given the links between social anxiety and attention to faces (Chen et al., 2002), between ASD and social anxiety (White et al., 2012), and the fact that the High and Low AQ Groups significantly differed on LSAS scores, Pearson's correlations between LSAS scores and the two Face Bias Scores were initially examined (Note that total LSAS scores were not added as a covariate in the ANOVA as LSAS scores significantly differed between groups as would be expected, thereby violating the assumption of independence of the covariate and group (Field, 2013; Miller & Chapman, 2001)). Neither correlation between LSAS scores and Face Bias Scores at 200ms or 500ms approached significance across all participants, all r's < .1, all p's > .32, or separately for the Low and High AQ groups, all rs < .18, all p's > .19.

Analyses

A mixed ANOVA was run on the Attention Bias score data with Group (Low AQ versus High AQ), Sex (male or female), Stimulus (face or car), and Time (200ms or 500ms) as the factors. The results revealed a main effect of Stimulus category, $F(1, 107) = 42.53$, $p < .001$, $\eta_p^2 = .284$, with Face Bias scores (mean = 19.77) being greater than Car Bias scores (mean = 2.25). The Stimulus x Group x Time x Sex interaction was also significant, $F(1, 107) = 5.55$, $p = .020$,

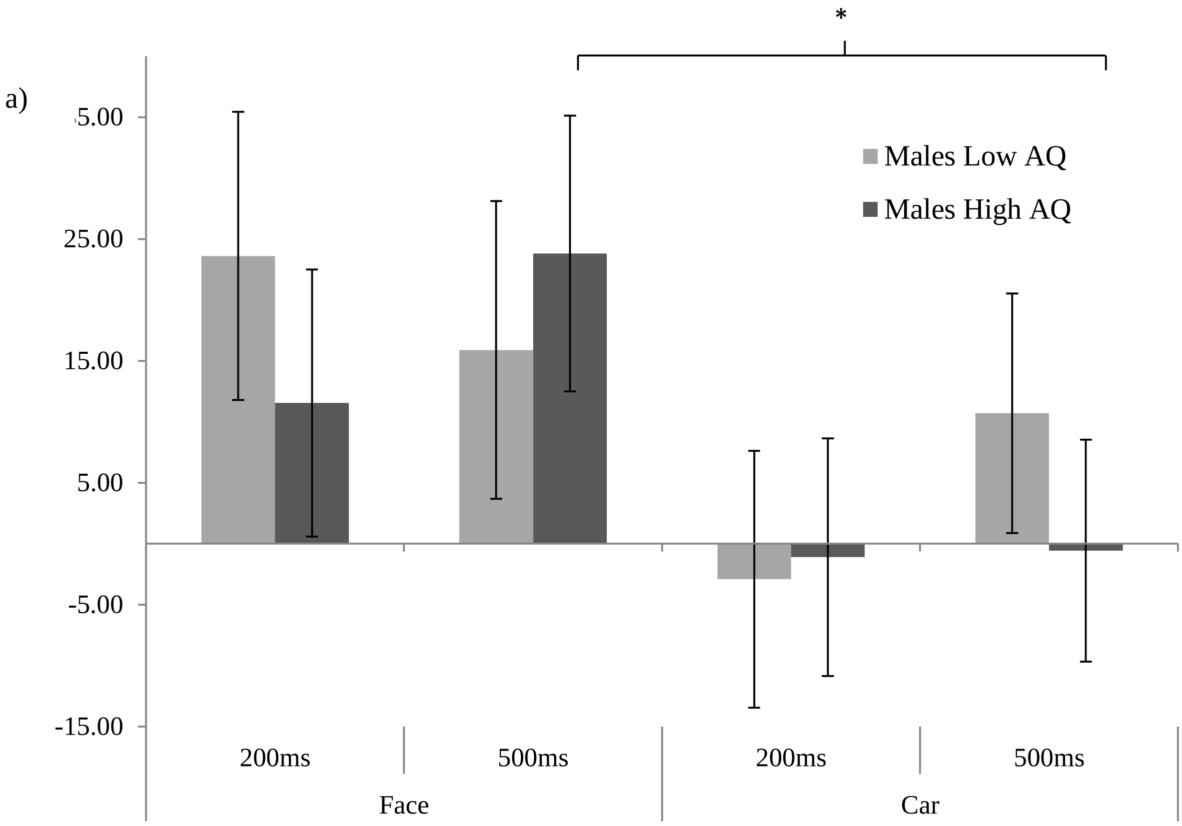
η_p^2 = .049. No other main effects or interactions were found to be significant, all *F*'s < 3.28, all *p*'s > .07.

To explore the significant four way interaction, a further Stimulus x Time x Group ANOVA was run separately for males and females. In females, there was a main effect of Stimulus, $F(1, 57) = 19.99$, $p < .001$, $\eta_p^2 = .260$, with Face Bias scores being greater than Car Bias scores. No other main effects or interactions approached significance, all *p*'s > .15 (see Figure 3b).

In males, results showed a main effect of Stimulus, $F(1, 50) = 24.23$, $p < .001$, $\eta_p^2 = .326$, again with Face Bias scores being higher than Car Bias scores. The Stimulus x Time x Group interaction was also significant, $F(1, 50) = 5.18$, $p = .027$, $\eta_p^2 = .094$.

To explore the three way interaction in males' scores, a Stimulus x Group ANOVA was run separately for 200ms scores and 500ms scores. At 200ms, there was a significant main effect of Stimulus only, $F(1, 50) = 14.34$, $p = .001$, $\eta_p^2 = .223$ with Face Bias scores being greater than Car Bias scores (means 17.58 and -2.01 respectively). The Stimulus x Group interaction was not significant, $F(1, 50) = 1.80$, $p = .19$, $\eta_p^2 = .035$.

At 500ms, there was a main effect of Stimulus, $F(1, 50) = 9.10$, $p = .004$, $\eta_p^2 = .154$, with Face Bias scores being higher than Car Bias scores (means 19.86 and 5.07 respectively). The Stimulus x Group interaction approached significance, $F(1, 50) = 3.83$, $p = .056$, $\eta_p^2 = .071$. Further T-tests were carried out on the 500ms bias scores in males to explore this trend. Paired-samples t tests were carried out on the 500ms display times within the High AQ group and revealed that Face Bias scores were significantly greater than the Car Bias scores, $t(27) = 3.80$, $p = .001$, $d = .66$ (see Table 4.3 for means). Within the Low AQ group, paired-samples t-tests showed no significant differences between Face and Car bias scores for the 500ms display times, $t(23) = 0.69$, $p = .495$, $d = .13$ (see figure 4.3). Independent samples t-tests showed no significant difference between high and low AQ groups for face, $t(50) = -0.84$, $p = .41$, $d = .23$, or car, $t(50) = 1.94$, $p = .06$, $d = .54$, bias scores at 500ms.



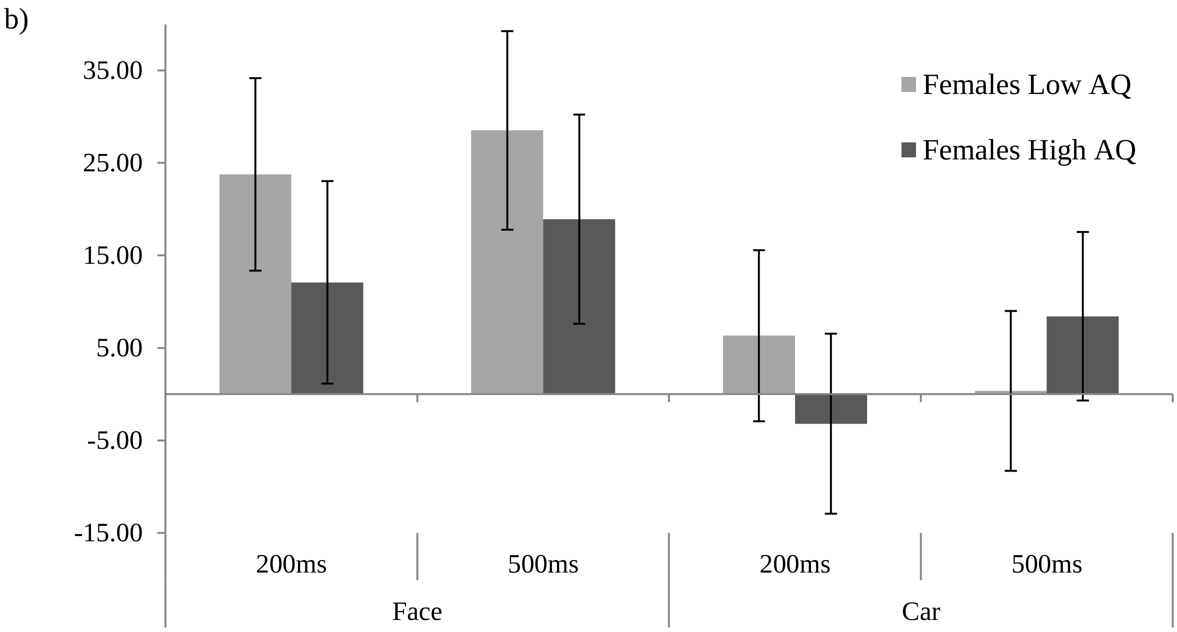


Figure 4.3. Mean bias scores for Low and High AQ groups for a) males and b) females for faces and cars at 200ms and 500ms presentation times. Error bars show 95% confidence intervals of the mean.

A bias score of zero indicates that reaction times were as fast to stimulus congruent trials as stimulus incongruent trials and neither of the images presented receive attentional priority, and suggests that both types of stimuli are attended equally across trials. Therefore if a bias score significantly differs from zero, this indicates that the attention bias was significantly greater towards the category of stimuli than the one it was paired with. To explore the extent that Bias scores differed from zero and therefore indicated an absolute attentional bias towards that item (as in e.g. Dalgleish et al., 2003; Moore et al., 2012; Roy et al., 2008), one sample t tests were conducted on each bias score, for each AQ group within males and females. As there were 16 comparisons, a Bonferroni correction was made resulting in an alpha value of .003.

For Low AQ males, the Face Bias at 200ms was significantly different from zero, $t(23) = 4.33$, $p < .001$, $d = 0.88$, but Face Bias scores at 500ms, $t(23) = 1.92$, $p = .067$, $d = 0.39$, Car Bias scores at 200ms, $t(23) = -0.56$, $p = .581$, $d = -0.11$, and Car Bias scores at 500ms, $t(23) = 2.72$, $p = .012$, $d = 0.55$, did not significantly differ from zero.

For High AQ males, the Face Bias at 500ms was significantly different from zero, $t(27) = 4.68$, $p < .001$, $d = 0.88$. Face Bias scores at 200ms, $t(27) = 2.59$, $p = .015$, $d = 0.49$, Car Bias scores at 200ms, $t(27) = -0.22$, $p = .826$, $d = -0.04$, and Car Bias scores at 500ms, $t(27) = -0.14$, $p = .894$, $d = -0.002$, did not significantly differ from zero (see Figure 3a). Taken together, these one sample t-tests on attention bias scores in males suggest that whilst both groups had greater attention bias scores to faces compared to cars at 200ms presentation times as shown in the ANOVA, for the high AQ males this was not an absolute attention bias whereas it was for the low AQ males. At the presentation time of 500ms, the low AQ males do not show a significant attention bias to faces or cars, whereas the high AQ males do show an absolute attention bias to faces but not to cars.

For Low AQ females, Face Bias scores at 200ms, $t(30) = 3.95$, $p < .001$, $d = 0.71$, and Face Bias Scores at 500ms, $t(30) = 5.81$, $p < .001$, $d = 1.04$, were both significantly different from zero. Neither Car Bias scores at 200ms, $t(30) = 1.31$, $p = .20$, $d = 0.24$, nor at 500ms, $t(30) = 0.07$, $p = .947$, $d = 0.01$, differed significantly from zero. For High AQ females, Face Bias scores at 500ms were also significantly different from zero, $t(27) = 3.89$, $p = .001$, $d = 0.74$, but Face Bias scores at 200ms, $t(27) = 2.05$, $p = .050$, $d = 0.39$, Car Bias scores at 200ms, $t(27) = -0.67$, $p = .511$, $d = -0.13$, and Car Bias scores at 500ms, $t(27) = 1.86$, $p = .073$, $d = 0.35$, did not significantly differ from zero.

Discussion

Overall faces were found to capture attention more than cars, however, the relationship between attention biases towards faces and cars was found to differ between sex and levels of autism traits. Males with both high and low levels of autism traits were found to orient attention more to faces than cars when stimuli were presented for 200ms. However, only the low autism trait males were found to demonstrate an absolute attentional bias towards faces at this display presentation time whereas the high autism trait males' mean attention bias scores towards faces did not differ from chance level. When stimuli were presented for 500ms, the males with low autism traits did not show any difference in attention bias scores to faces or cars, and neither score showed an absolute attentional bias. However, the males with high autism traits showed an absolute attention bias towards faces which was greater than towards cars when stimuli were presented for 500ms. All females were found to show greater attention biases towards faces than cars, although a similar pattern to that seen in males was observed when considering the extent to which attention biases differed from chance in females. Females with low levels of autism traits were found to show an absolute attentional bias towards faces at both 200ms and 500ms, whereas the females with high autism traits only demonstrated an absolute attention bias towards faces at 500ms. There was no evidence found of greater orienting of attention towards cars in those with high levels of autism traits.

At 200ms, males with both high and low levels of autism traits were found to orient attention to faces to a greater extent than cars. Therefore there is an indication that selective attention is preferentially allocated to faces to a greater extent than cars even in those with high levels of autism traits. At first this seems indicative of intact rapid orienting of attention in these groups, and appears contrary to Moore et al. (2012) who found that participants with ASD showed a reduced attention bias to faces when stimuli were presented for 200ms in a dot probe task. However, exploration of the extent to which the bias scores for each stimulus represented an absolute bias to preferentially allocate attention towards them, found that the males with low levels of autism traits showed an absolute attentional bias towards faces at 200ms but not at 500ms. Males with high levels of autism traits showed the opposite pattern with an absolute bias towards faces only emerging when stimuli were presented for 500ms. This pattern is more supportive of Moore et al. (2012) and suggests that social orienting differences in ASD may be present to a lesser extent in the subclinical autism spectrum. It is acknowledged that these results should be interpreted with caution as the main analysis produced only a trend. However, the present study provides preliminary evidence that social orienting in the subclinical autism spectrum may be atypical, and the time course of the social orienting differences suggest that face processing may also be related to subclinical autism traits.

Previous research has found that attention can orient overtly to faces in 100ms in typical development (Crouzet et al., 2010). It is thought that face detection occurs rapidly and that attention selectively engages with faces over other objects in typical development (Palermo & Rhodes, 2007). The presentation time of 200ms was used to capture this rapid attentional bias towards faces. It is thought that in ASD, face processing is atypical and may rely more on slower top down strategies rather than the rapid configural processing by which faces are typically identified (Lahaie et al., 2006; Neumann et al., 2006). It has been suggested that this is due to a lack of cortical specialisation for faces in ASD (Schultz, 2005). Face processing atypicalities have also been identified in the BAP. Adolphs et al. (2008) found that parents of children with ASD who displayed ‘aloof’ BAP characteristics demonstrated an over reliance on facial information from the mouth as opposed to eye region when identifying facial emotions. This pattern of face processing has been widely reported in individuals with ASD (Klin et al., 2002; Neumann et al., 2006). Therefore it seems that atypicalities in face processing found in ASD are also evident in the subclinical spectrum of autism traits. The results relating to the strength of attention biases in the present study support this by suggesting that males with high levels of autism traits may beslower to attend to faces indicating that broader social attention differences also fall on a subclinical spectrum with autism traits, potentially as a result of slower mechanisms of face processing.

The Social Motivation theory of ASD (Chevallier et al., 2012) argues that individuals with ASD are not motivated to preferentially attend to the social world. The present findings relating to the strength of each attention bias score suggest that males with high autism traits do preferentially orient to social information, however, they may be slower to do so. If males with high levels of autism traits do display a delayed attention bias to faces at 500ms presentation times, this is suggestive of the use of voluntary, top down processes (Müller & Rabbitt, 1989) and indicates that these participants were motivated to attend to faces. The high autism trait males showed a reduction in the rapid, automatic orienting to faces, thereby potentially implicating a reduction in either cortical specialisation for face detection (Kleinhans et al., 2011), or diminished subcortical face detection via the amygdala which are linked to the rapid detection of faces (Johnson, 2005), although tests relating to neurological functioning were not performed in the present thesis. The presence of an attention bias towards faces at 500ms, however, suggests these differences in rapid automatic orienting can be compensated for by slower top down processes. This would indicate that males with high levels of autism traits do have motivation to attend to social information but may be slower to do so.

However, whilst analysis of each attention bias score provides interesting preliminary suggestions that attention orienting towards faces may occur at different times in males with high and low levels of autism traits, this was not necessarily supported by the main analysis. The interaction between stimulus category and autism trait group within males showed that males with both high and low levels of autism traits oriented towards faces to a greater degree than cars at the faster presentation duration of 200ms. Males with low levels of autism traits did not differ in the extent to which they oriented to faces and cars when displayed for 500ms, with males with high levels of autism traits orienting to faces to a greater degree than cars at this longer duration. Although, again, it should be noted that this result was only a trend and therefore should be interpreted with caution. This analysis appears to suggest that it is the low autism trait males who are unusual in that faces are not capturing and holding attention any more than cars when participants have longer to look at the stimuli at the 500ms presentation duration. This unusual finding may be because the stimuli were incidental to the target detection task, and therefore allocating attention preferentially to any one kind of stimuli is not beneficial to task completion. Previous research has shown that males are more focused on completion of the task in similar target detection tasks and less affected by irrelevant distractor stimuli than females (Bayliss et al., 2005; Stoet, 2009). This may be why the low autism trait males were displaying no difference in their allocation of attention to the different types of stimuli at a longer duration where interest in completing the task may override initial biases towards faces. It is also possible that the low autism trait males were more interested in the car stimuli than the high autism trait males, contrary to predictions. This could either be because of the configural similarity of the cars to faces, or because of a genuine interest in cars in this group. Cars may be more representative of male interests generally than specifically circumscribed interests in ASD. As discussed below, trains are often used as objects of high autism interest in attention research (e.g. Fischer et al., 2013) and images of cars may not have captured the nature of circumscribed interests relating to ASD. Conversely, the high autism trait males may have maintained their attention on the face stimuli over the longer 500ms period for the reasons relating to slowed processing noted above, which may have made it necessary for males with high levels of autism traits to maintain attention to faces for longer than males with low levels of autism traits in order to process the content of the stimuli. Therefore, overall it appears that there is some difference in the time course of attentional biases towards faces in males with high and low autism traits, potentially as a result of slower methods of face processing in those with high levels of autism traits, but this difference is not clear cut and requires further investigation.

The possible delay in social orienting could be in line with the findings of Townsend, Harris, and Courchesne (1996), who found that participants with ASD showed a slowed orienting of attention. Those with ASD benefited more from spatial cues over longer durations than controls when identifying targets at the cued location. However, there was no difference in overall reaction times between those with high and low levels of autism traits in the present study indicating no difference in the speed of orienting or responding. Therefore it is unlikely that slowed orienting explains this finding because the groups were equally fast to orient to the target.

The group difference between those with high and low levels of autism traits in attentional biases towards faces was only evident in males. Females with high and low levels of autism traits showed a greater attention bias to faces than cars at both stimulus presentation times. However, when looking at the degree of attentional bias for faces and cars within females, it was found that absolute face bias scores were evident at both 200ms and 500ms presentation times for females with low levels of autism traits. For the females with high levels of autism traits, an absolute attentional bias towards faces was evident at 500ms but not at 200ms suggesting a similar pattern of delayed orienting to faces as seen in males. However, this effect was not as strong in females and was not supported in the main analysis. This is in line with the hypothesis that attentional differences in relation to autism traits would be shown to a greater extent in males than females, as would be suggested by the EMB theory. Additionally, the females with low levels of autism traits demonstrated an absolute attention bias to faces at both 200ms and 500ms, whereas males with low levels of autism traits showed an attentional bias to faces only at 200ms. Females are found to be more interested in the social world than males (Baron-Cohen & Wheelwright, 2004; Bayliss et al., 2005) which could explain why females with low levels of autism traits maintained attention to faces at the longer presentation duration whereas the males did not.

No attention biases were found towards cars for either sex or across autism trait groups. This shows that cars did not immediately capture the attention of any of the groups of participants in the same way as faces, and in fact any more or any less than the neutral condition of houses. It was predicted that those with high levels of autism traits would show an attentional preference for the cars, and that this would be strongest in the males with high levels of autism traits. The EMB theory (Baron-Cohen, 2002), research around sex differences in intense interests (DeLoache et al., 2007), and looking behaviour to social and mechanical objects (Connellan et al., 2000) would suggest that cars may be of greater interest to those with more autism traits, especially males. The EMB theory posits that males have a greater preference for closed systems and less of an interest in the social world than females. Therefore it would be expected that males may show an enhanced attention bias towards mechanical objects. However, across all participants, faces were found to capture attention to a greater extent than cars. Sasson and Touchstone (2013) found that objects of circumscribed interest were given attentional preference over faces when these two types of images were paired together. The present study did not support this finding as cars were not found to elicit a strong attentional bias in relation to autism traits. One reason for the difference between the present study and that of Sasson and Touchstone could be that the use of the car images may not have encapsulated the 'mechanical' image that was aimed for. Cars were selected owing to their visual similarity to faces to limit low level visual differences between the images being presented. However this selection may not represent the diversity in content of circumscribed interests found in ASD. In future research a wider range of mechanical objects can be used to test out the attentional biases associated with different categories, such as other vehicles, or objects relating to scientific interests such as telescopes (South et al., 2005; Turner-Brown et al., 2011). In future research it would also be beneficial to explore attention biases towards objects of circumscribed interests by identifying interests specific to the participant, as in Singleton et al. (2014). Images relating to these interests could then be used as stimuli.

The lack of attention towards cars might have been influenced by the nature of the stimuli, as cars were rated as less complex and less interesting than the house images that they were paired with. If these two factors were influencing attention biases towards cars and houses, it would be expected that there would be a greater attentional bias towards houses when paired with cars. This would be evidenced by a negative attention bias score towards cars. However, reaction times were approximately equal whether the target was shown in the location of the car or house stimuli. Therefore neither houses nor cars appear to be superior in terms of attentional saliency.

It should be noted that the face stimuli were rated as more negative than the house stimuli, which could result in attention being drawn towards faces as negative stimuli have been found to capture attention (Biggs et al., 2012). However, faces were not found to differ in valence from cars, therefore it would be expected that valence would impact cars in the same way, and no absolute biases towards cars were found.

Inter-trial priming effects have been found within visual search experiments (Meeter & Olivers, 2006) and could have impacted on the results presented in this chapter. In terms of the present study, inter-trial priming would be demonstrated by faster reaction times when a target appeared in location of the same type of stimulus as the trial before. Exploring whether inter trial priming occurred differentially for participants with high and low levels of autism traits for the different stimuli would present an interesting avenue for investigation in future research. It might be expected that participants with low levels of autism traits demonstrate greater inter trial priming when the target appears in the location of a face stimulus in two subsequent trials relative to other types of stimuli, and to participants with a greater number of autism traits. This may be because participants with higher levels of autism traits have less of a bias towards faces than those with lower levels.

The findings could have been further impacted by IoR in the present study as display durations of 500ms were used and IoR has been found to occur in target detection when cues are displayed for over 300ms (Klein, 2000). This would be demonstrated by participants being slower to identify targets in the location of the stimulus they were attending than in the location of the unattended stimulus. However, the dot probe experiment involves simultaneous presentation of two stimuli which are incidental to the location of the target. Therefore, unlike in peripheral cueing tasks where inhibition of return is known to occur, the stimuli do not act as cues because no one type of stimulus is exogenously capturing attention and both are competing for selective attention. Furthermore, it was anticipated that participants would demonstrate greater attention bias scores towards face stimuli than car stimuli as a result of greater salience of faces than cars. This prediction was supported. If participants were selectively attending to the face stimuli compared to other stimuli as would be predicted from previous research (e.g. Bindemann et al. 2005), and IoR had occurred, there would have been a negative attention bias score for the face stimuli as participants would be faster to identify the target when it appeared in the opposite location to the face. This was not found to be the case. Therefore it is unlikely that IoR had a notable impact on the present results.

Social anxiety scores were found to differ between those in the Low and High AQ groups, in line with previous research indicating that AQ scores are positively related with social anxiety (White et al., 2011). However social anxiety scores were not found to be related to the attention bias to faces in the present study. This is contrary to the findings of Chen et al. (2002) who found that individuals with social phobia orient away from faces. This difference could be that Chen et al (2002) used a clinical population of individuals with a diagnosis of social phobia. However, Garner et al. (2006) used participants from the general population and separated them into high and low scoring groups on measures of social anxiety, and found that those with high social anxiety initially direct their gaze towards faces over objects more than low social anxiety participants. Garner et al.'s (2006) study differed from the present experiment in that eye tracking measures were used to determine where participants initially fixated, rather than using the reaction time data from the dot probe task. Images were displayed for 1,500ms and the measure of which picture the first fixation fell on was determined by the criteria of occurring at least 100ms after image onset and before image offset at 1,500ms. Therefore the eye tracking equipment may have picked up subtler differences that occur in visual attention as early as 100ms which are missed in analysis of reaction time trials which involve 200ms of presentation time, followed by response time. As such, an impact of social anxiety on visual attention to social information in relation to autism traits cannot be ruled out entirely, and it remains important to consider its impact in social attention research.

In conclusion, overall, participants showed an attentional preference for faces over cars so it appears that those with high levels of autism traits do orient attention to social information, however the time course over which this occurs appears to vary. A trend was found for males with high and low levels of autism traits to vary in the time course of attentional orienting to faces and cars, with some evidence to suggest that males with high levels of autism traits are slower to orient to faces. There was some evidence of a similar pattern shown to a lesser extent in females with high and low levels of autism traits. It is suggested that this may be because of a difference in face processing styles in relation to subclinical traits similar to that seen in ASD. Therefore, there may be a reduction in automatic orienting to faces in the subclinical autism spectrum, but it is compensated for by slower attentional top down mechanisms which show evidence of some intact social motivation. This requires further investigation as these findings were mainly supported by analysis of absolute attention biases rather than the main analysis. No evidence was found for an attentional bias towards car stimuli in relation to autism traits. This may be a facet of the type of stimuli used rather than a genuine lack of interest in areas of circumscribed interest that are frequently identified in ASD.

Chapter 5

Disengaging Attention from Social and Mechanical Objects In the Subclinical Autism Spectrum

Chapter Abstract: Chapter 5 investigates whether faces or objects of circumscribed interest differentially hold attention in relation to subclinical autism traits. The present study used a peripheral cueing task which exogenously orients attention to a cue. The latency to disengage attention is revealed by the difference in reaction time to identify a target that is invalidly cued compared to when it is validly cued. All participants were found to be slower to disengage from face cues than car cues, and this did not vary in relation to autism traits. Additionally, males were found to be slower to disengage from all cues as well as being faster to orient to them in the first place.

Chapter 4 measured the rapid attentional capture of faces and objects of circumscribed interest in relation to autism traits. The present study further explored social and non-social attention by examining the extent to which these types of objects hold attention in relation to autism traits. Previous research indicates that people are slower to disengage attention from stimuli that are salient to the individual. This can mean that the stimuli are rewarding, threatening, related to goals of the current task, arousing or behaviourally relevant to the individual (Frewen et al., 2008; Vogt et al., 2008). As such, measuring the disengagement of attention from different types of stimuli reveals the saliency of images through top down biases.

There is disagreement within the literature as to whether the general ability to disengage attention is impaired in ASD. Some research finds that individuals with ASD are slower to disengage attention than typically developing controls (Bedford et al., 2014; Landry & Bryson, 2004; Zwaigenbaum et al., 2005), however other research finds that there is no difference between individuals with ASD and typically developing controls in the disengagement of attention (Fischer et al., 2013; Iarocci & Burack, 2004).

Few studies have investigated whether the ability to disengage attention is related to subclinical autism traits. Ibanez, Messinger, Newell, Lambert, and Sheskin (2008) investigated the disengagement of visual attention in siblings of those with ASD, as similar characteristics to ASD are reported in those with the BAP (Piven et al., 1997). They compared gaze patterns of six month old infants who were siblings of a child with a diagnosis of an ASD, to gaze patterns of siblings of typically developing children. The frequency of gaze shifts were measured whilst the infants were interacting with their caregiver. It was found that siblings of a child with ASD displayed fewer gaze shifts than the control siblings, and longer fixations away from their parents. The authors suggest that this indicates deficits in the ability to disengage attention in the BAP as they were maintaining fixations for longer. Similarly, Elsabbagh, Volein, Holmboe, et al. (2009)

found that 10 month old siblings of those with an ASD were slower to disengage attention in a gap overlap task than control siblings. These two studies suggest that difficulties disengaging attention which have been documented in ASD may also be present in relation to subclinical levels of autism traits. However, both of these studies looked at siblings where there was already an incidence of ASD in the family, and therefore they were more likely to display higher levels of traits associated with autism (Piven et al., 1997). They also investigated the attentional behaviour of infants, and the disengagement of attention is a developmental acquisition (Johnson, Posner, & Rothbart, 1991). Therefore the ability to disengage attention could improve in individuals with ASD and subclinical autism traits. However, no studies to date have investigated whether general disengagement abilities vary with different levels of autism traits in adults from the general population. Exploring general disengagement abilities in relation to subclinical autism traits will contribute to the debate as to whether disengagement is typical or atypical in ASD.

More specifically, the present study is also concerned with the effects of the type of stimulus participants are to disengage from. Faces are known to receive attentional priority for the majority of people (e.g. Bindemann et al., 2007; Frank et al., 2009), but as described in previous chapters, individuals with ASD may not have this same attentional preference for faces (see Guillon et al., 2014 for a review). In addition to an early emerging orienting preference towards social information in typical development, there is evidence to suggest that faces also hold attention and result in slower disengagement for typically developing infants. DeNicola, Holt, Lambert, and Cashon (2013) found that the attention of infants aged 4 to 8 months was held by images of faces when they were presented with images of toys across 10 second trials. This suggests that while these infants had the general ability to disengage attention, they were particularly slow to do so when looking at faces as opposed to other objects. Bindemann et al. (2005) found that faces impeded performance on a Go/No Go experiment relative to other objects, indicating slower disengagement from faces, and Ro et al. (2007) found that faces interfered more with target detection than other objects. Therefore not only do faces immediately capture attention to a greater extent than other objects, they also ensure that it remains in that location. Bindemann et al. state that the reason that faces retain attention may be that it facilitates face processing in terms of identification of the individual.

This tendency to maintain attention to faces to a greater extent than other objects may not be present in individuals with ASD. Chawarska et al. (2010) found that typically developing and developmentally delayed toddlers had difficulty disengaging their attention from faces whereas toddlers with ASD did not. This shows that typically developing children are slower to disengage from faces whereas children with ASD are not. Similarly, Kikuchi et al. (2011) found that typically developing children were slower to disengage from faces in a gap-overlap experiment whereas children with ASD showed no difference in the time taken to disengage visual attention from face or non-face stimuli.

No research has directly measured attentional disengagement from faces in relation to subclinical autism traits in the general population, but there is some evidence to suggest that there is atypical disengagement of attention from faces in the BAP. Rutherford (2013) found that infant siblings of a child with ASD spent significantly less time looking at a face image when it was presented with a luminance and contrast matched foil than control siblings and that this difference increased from 3 months of age to 6 months. This suggests that the BAP is associated with diminished social attention similar to that seen in individuals with ASD, and that faces do not hold the attention of infant siblings of individuals with ASD as much as control siblings. Establishing whether faces hold attention in subclinical autism traits elucidates the extent to which faces are important in relation to autism traits as disengaging attention is driven by top down modulation (Theeuwes & Belopolsky, 2012) and therefore internal goals and beliefs of the observer.

Social anxiety has been widely researched in relation to disengaging attention from faces as a potential source of threatening information (Fox, Russo, & Dutton, 2002), and individuals with ASD often have been found to have elevated levels of social anxiety relative to typically developing individuals (White et al., 2012). The relationship between social anxiety and traits of autism is also seen in the general population, as White et al. (2011) found that AQ scores were positively correlated with a social anxiety measure in sub clinical college students. Peripheral cueing tasks are used within social anxiety research to explore the disengagement of attention from threatening faces (e.g. Amir, Elias, Klumpp, & Przeworski, 2003; Fox et al., 2001). It is thought that an inability to disengage attention from the object of fear may contribute to the maintenance of a phobia (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007). As such, it is possible that individuals with high levels of autism traits may show a slower disengagement from faces if they are objects of social anxiety. Ashwin, Wheelwright, and Baron-Cohen (2006) found that faces produced an interference effect on colour naming in a Stroop task for individuals with ASD over non-social objects. These results are interpreted as being indicative of the attentional capture of faces in individuals with ASD, and it is suggested that this could be because of a greater anxiety induced in individuals with ASD than control participants. Therefore social anxiety was measured in the present study to establish whether it was influencing the disengagement of attention from faces in the present study.

Research has found that individuals with ASD may have an attentional preference to objects that are of particular interest to them rather than faces (Grelotti et al., 2005; Sasson & Touchstone, 2013). It is possible that whilst it would be expected to see a slowed disengagement from faces in typical development due to a heightened interest in faces, individuals with ASD may demonstrate slowed disengagement from objects which are of particular interest to them. No research as yet has looked specifically at the disengagement of attention from objects of circumscribed interest in subclinical autism traits. Grelotti et al. (2005) found that their subject with ASD demonstrated greater activation in the Fusiform Face Area (FFA) of the fusiform gyrus in response to images of Digimon, his particular area of circumscribed interest, but not to faces. In accordance with the Social Motivation Theory of autism (Chevallier et al., 2012), it could be the case that people with ASD are not motivated to pay attention to faces and therefore develop cortical specialisation in relation to subjects which are of more interest to them. One recent study has found a positive relationship between AQ scores and physiological arousal when looking at images of non-social stimuli (Singleton et al., 2014) therefore it might be expected that non-social images, and particularly images of objects that may be of circumscribed interest, will hold attention to a greater extent in those with high levels of autism traits than low levels.

As discussed in previous chapters, females are found to exhibit greater attentional preference to social information than males (e.g. Connellan et al., 2000; Lutchmaya & Baron-Cohen, 2002), and males are identified as displaying more traits associated with autism than females (Baron-Cohen, 2002; Baron-Cohen, Wheelwright, Skinner, et al., 2001). Males may also have a greater preference for objects which have been identified as being of circumscribed interest to individuals with ASD such as mechanical objects, in accordance with a greater systemising tendency in males (Baron-Cohen, 2002; DeLoache et al., 2007). Therefore it is again important to consider sex when investigating attentional measures of interest in social and mechanical objects as differences in attention to social and non-social objects may differ in their relationship to autism traits across sex, as females with high levels of autism traits may be more social than males with high levels of autism traits and therefore attend more to social stimuli than males, whereas the males with high autism traits may attend more to non-social stimuli than females as males have been found to have more non-social interests than females.

The present study used a peripheral cueing technique to investigate the disengagement of attention from social and mechanical objects in relation to autism traits in the general population. A peripheral cueing task was used to examine the disengagement of attention once it has been exogenously oriented covertly to a stimulus. Exogenous cueing experiments ensure attention is shifted to the stimulus of interest as the shift in attention is automatic (Jonides, 1981). The use of covert measures of attention ensures that differences in reaction times are not the result of group differences in the time taken to make a saccade (Posner, 1980) as there is some evidence that saccade speed may be slowed in ASD (Schmitt, Cook, Sweeney, & Mosconi, 2014). Images of faces were used as peripheral cues to capture disengagement from social stimuli. Cars were used to represent a mechanical class of objects which have been identified as being of circumscribed interest to individuals with ASD (Baron-Cohen & Wheelwright, 1999; South et al., 2005).

Typically, peripheral cueing experiments present cues for 100ms (e.g. Fox et al., 2001; Posner, 1980) as this has been found to be sufficient to exogenously shift attention and ensure its engagement at the cued location (Posner, 1980). Müller and Rabbitt (1989) identified a window of 100-150ms as optimal cue presentation times for exogenous orienting experiments. This is also sufficient time for rapid face detection to occur (Crouzet et al., 2010) and so is long enough for disengagement biases to be illuminated. Townsend, Harris, et al. (1996) found that participants with ASD showed an increased benefit from valid cues relative to invalid cues (the validity effect) when they were displayed for 800ms, compared to 100ms, in a peripheral cueing task. In contrast, the control group showed optimal performance when they were presented for 100ms. Similarly, Wainwright-Sharp and Bryson (1993) found that ASD participants displayed a benefit from valid cues when cues were presented for 800ms, but not 100ms, in a central cueing experiment. The authors suggest this is because the ASD participants were slower to process the information from the central cues. Therefore, the present study used cue presentation durations of 100 and 800ms as greater validity effects might be seen in individuals with high levels of autism traits when stimuli are presented for longer durations. It is noted that although 800ms is long enough to induce IoR in typically developing populations, the ASD group did not appear to be showing IoR in Townsend et al.'s (1996) study. Additionally, cues which are predictive (validly cue the target more than they invalidly cue the target) have been found to overcome IoR effects (Pruett et al., 2011), and were used in the present study.

The aims of this experiment were: (1) to explore whether any differences in the disengaging of attention may depend on whether the cues are social or mechanical stimuli in relation to autism traits, (2) to investigate general differences in the disengagement of attention in relation to subclinical autism traits in the general population, (3) to test if the time course of the cue presentation may affect disengaging attention from different objects in relation to autism traits, and (4) to test sex differences in disengaging attention from social and non-social stimuli in relation to autism traits. It was hypothesised that those with low levels of autism traits would be slower to disengage attention from face stimuli than car stimuli, but that those with high levels of autism traits would be slower to disengage attention from car stimuli than face stimuli. It was further hypothesised that participants with high levels of autism traits would show a general slowing of disengagement in their reaction times to invalid trials relative to valid trials. It was expected that differences in disengaging attention from face and car stimuli may be elucidated when stimuli were presented for 800ms rather than 100ms, and that differences in disengaging attention from social and mechanical objects may be more pronounced in males than females.

Methods

Participants

Ninety-six adults (47 male and 49 female; mean age = 27.99, SD = 6.54) were recruited from the University of Bath community to take part in this study in exchange for £10. Participation was advertised via posters around the University and an online noticeboard on the university website. Sixty three participants identified themselves as white European, 16 as Chinese, 3 as Indian, 2 as Pakistani, 2 as White Other, and one each of Other Asian, Australian, Caribbean, Japanese, Middle Eastern, Persian, White American, White and Asian, White and Black and White Latin. The majority of participants were undergraduate or post graduate students at the University of Bath (57; 59.4%), with the remaining 39 (40.6%) participants holding various positions across the university (e.g. administration, research, lecturer, fundraiser). Participants all had normal or corrected to normal vision, were not taking any medication that affected their cognitive abilities, and did not report having any current psychiatric diagnoses.

Participants were split into two groups based on their AQ score using a median split. Those with scores below the AQ median of 17 formed the ‘Low AQ’ group and those with scores at the median or above formed the ‘High AQ’ group. Descriptive statistics for these groupings are shown in table 1 (two participants have been excluded due to the number of errors made in the task, see Data Preparation section below). The participants in the high and low AQ groups did not significantly differ in age, $t(92) = 1.87$, $p = .064$, or the number of males and females in each group, $\chi^2(1, N = 74) = 1.07$, $p = .302$. The high AQ group had significantly higher AQ scores, $t(92) = -12.40$. $p < .001$, and LSAS scores, $t(92) = -4.14$, $p < .001$, than the low AQ group, as would be expected.

Table 5.1

Mean (SD) questionnaire scores and demographic information for Low and High AQ groups

	Low AQ (N = 45)	High AQ (N = 49)	Overall (N = 94)
Sex ratio (Males: Females)	20:25	27:22	47:47
Mean Age	29.12 (7.42)	26.59 (5.64)	27.80 (6.64)
Mean AQ score**	11.91 (3.45)	22.51 (4.69)	17.44 (6.73)
Mean LSAS score**	33.71 (14.77)	48.16 (18.66)	41.24 (18.32)

** $p < .001$ for difference between groups

Note: AQ = Autism Spectrum Quotient (maximum score 50); LSAS = Leibowitz Social Anxiety Scale (maximum score 144)

Materials

The AQ (Baron-Cohen, Wheelwright, Skinner, et al., 2001) was used to assess the extent to which participants displayed autism-related traits. The AQ is a 50 item self-report measure of traits associated with autism with a maximum score of 50. Higher scores indicate greater levels of autism traits. See Materials section in Chapter 4 for further description of the AQ.

The LSAS (Baker et al., 2002) was administered to explore whether social anxiety was related to disengaging attention from faces. This measure presents 24 social situations (e.g. “Going to a party”) covering social interactions and performance situations which the participant has to respond how much they fear that situation from 0 (no fear) to 3 (severe fear), and how much they avoid that situation from 0 (never) to 3 (usually). This results in two subscales of Fear and Avoid which make up the total LSAS score. Total scores can range from 0 to 144. See Materials section in Chapter 4 for further description of the LSAS.

Peripheral cuing task stimuli

Ten images of neutral faces (5 female and 5 male) taken from the KDEF (Lundqvist & Litton, 1998), and ten car and ten house images from public domain websites were used to create stimuli as described in the Stimuli section in Chapter 4. All images were set to greyscale and extraneous features were eliminated with the same pale grey colour as the background they were presented on. These stimuli were also included in the stimuli validation process described in Chapter 4, but were not presented in the dot probe task. Houses were used as filler trials to reduce participants’ awareness of the aims of the experiment.

Procedure

Participants were tested individually in a quiet research laboratory at the University of Bath and seated with their eyes approximately 57cm away from the centre of the computer screen. For the peripheral cueing task, 18 practice trails were initially completed to familiarise the participants with the procedure.

Each trial began with the presentation of a black central fixation cross on a grey background flanked to the left and right by two black rectangular outlines for 1000ms. Each rectangle subtended 6° of visual angle and measured 7.2 x 9.6cm. The centre of each was 9° from the central cross. Participants were instructed to remain fixated on the central cross throughout (as in Bayliss et al., 2005; Mogg et al., 2008). This ensured attention was captured covertly to ensure reaction time differences were not contingent on the time taken to make a saccade (Posner, 1980). The initial screen was immediately followed by the presentation of a stimulus cue consisting of either a face, a car or a house in either the left or right box. The stimuli appeared in the box for either 100 or 800ms. Following the offset of the cue, the boxes remained blank for 50ms. The target was then presented in one of the two boxes. The target was either two vertically aligned dots (:) or two horizontally aligned dots (..) subtending 1° of visual angle which remained on screen for 2s or until response, whichever was first (see Figure 1). The participant responded by pressing a button on the keyboard corresponding to the vertically or horizontally aligned dots.

Accuracy and reaction times to identify the target were recorded. A trial ended when the participant responded or to a maximum of 2000ms. After the end of a trial, an inter-trial interval of 500ms preceded the subsequent trial.

When the target appeared in the same box where the stimulus appeared preceding it, this was a valid trial. When the target appeared in the location of the box where the preceding stimulus did not appear, this was an invalid trial. Each of the 30 stimuli were presented as valid cues (240 trials, 80 of each type of stimulus) twice as often as invalid cues (120 trials, 40 of each type of stimulus). Each image was shown at both presentation durations, and each presentation location, resulting in the 360 experimental trials. The type of target (: or ..) was randomised throughout. The ratio of two thirds valid trials and one third invalid trials was chosen because previous research has reported that a greater proportion of trials are required to be valid, rather than invalid, in order to produce costs and benefits of invalid and valid cues (Jonides, 1981).

Participants completed the AQ and LSAS on computers in the laboratory via Bristol Online Surveys. Half the participants completed the questionnaires first and the other half completed the peripheral cueing task first. Additionally the order of the two questionnaires was randomised between participants.

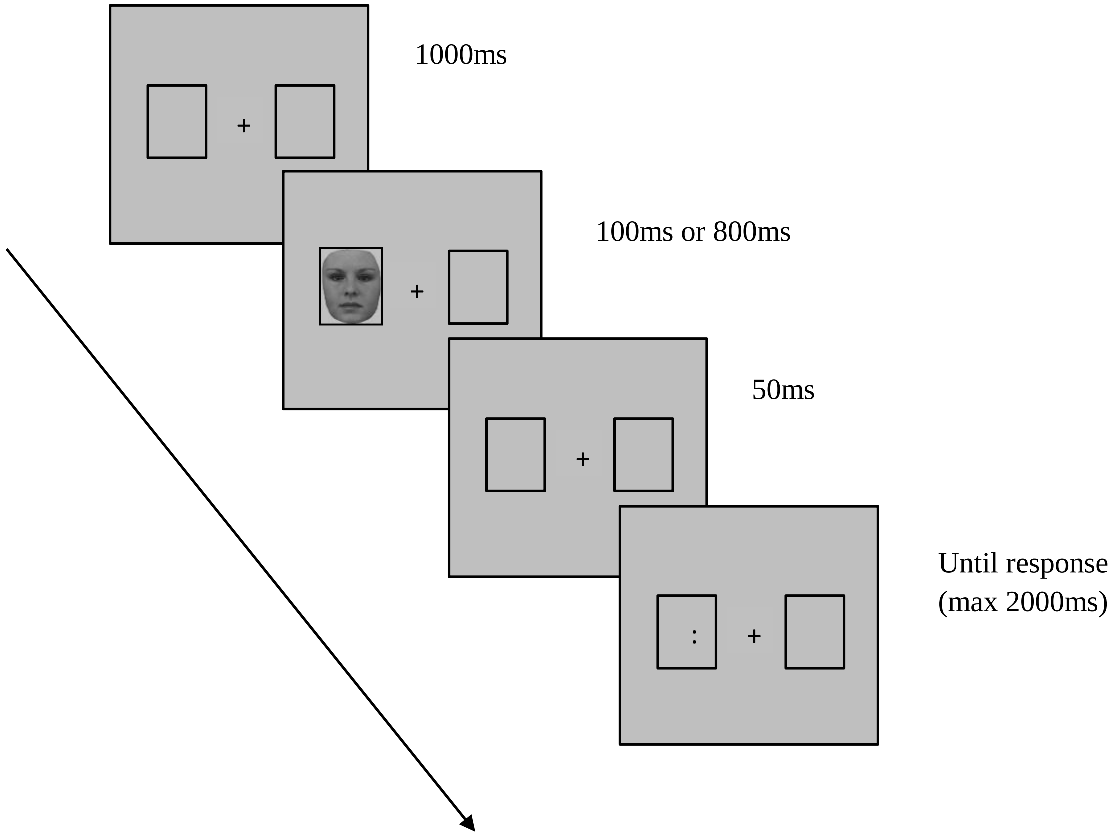


Figure 5.1. An example of a valid experimental trial. The central fixation cross flanked by two boxes is presented for 1000ms, followed by the presentation of a cue in one of the boxes. The cue disappears for 50ms and is replaced by the target until response or for a maximum of 2000ms. An inter trial interval of 500ms with a blank screen follows. For invalid trials, the target is presented in the opposite location to that which the cue was presented.

Results

Data preparation

Trials with erroneous responses and where reaction times were greater than 2.5 standard deviations from the participants mean were removed. Two participants' data was removed from further analyses owing to a proportion of errors 2.5 standard deviations greater than the sample mean (Cooper & Langton, 2006) indicating inattention or difficulty with the task (percentage errors for these two participants were 11.67% and 18.06%). 2.20% of data was removed due to outlying reaction times, and 2.49% due to errors, accounting for less than 5% of the data in total. The high and low AQ groups did not differ in the mean number of trials discarded due to errors, $t(92) = -1.16$, $p = .249$, or due to outlying data points, $t(92) = 0.19$, $p = .852$.

Mean reaction time scores were calculated for each cue type at each presentation duration for both valid and invalid trials (see Appendix III for raw reaction time data). Since the costs of an invalid cue relative to the benefits of a valid cue were of interest, reaction times to identify validly cued targets were subtracted from those to invalidly cued targets to produce a Validity Score to give a measure of the disengagement of attention (Townsend, Courchesne, et al., 1996). In this way, individual differences of general slower reaction times are eliminated, as is the time taken to initially orient to the cue. The validity score represents the time taken to disengage from the cue initially appearing on screen, and to move attention to the target appearing at the opposite location. This measure can be described as containing both the benefits of a valid cue, and the costs of an invalid cue (Jonides, 1981). Positive numbers indicate reaction times being faster to valid cues than invalid cues. Higher Validity Scores reflect greater time disengaging from the automatically cued item and to detect the subsequently appearing target. A negative Validity Score indicates that reaction times were faster when the target was invalidly cued. Validity scores were computed for each cue type at each presentation duration (see Table 5.2).

Table 5.2

Mean validity scores (SD) for face and car cues for males and females in high and low AQ groups

Cue	Presentation Time	Males Low AQ (n = 20)	Males High AQ (n = 27)	Females Low AQ (n = 25)	Females High AQ (n = 22)
Face	100ms	43.88 (45.92)	41.10 (33.39)	21.70 (38.21)	29.77 (47.48)
	800ms	8.40 (41.98)	15.67 (42.03)	-9.48 (48.58)	0.68 (45.26)
Car	100ms	34.89 (50.92)	17.13 (33.16)	14.38 (35.02)	23.32 (38.22)
	800ms	0.27 (35.16)	4.08 (33.06)	-17.26 (40.55)	-13.46 (36.40)

Reaction times to valid cues were compared to explore the orienting of attention in the present task, however this was not the main variable of interest as the current study is concerned with the disengagement of attention from social and non-social objects. Reaction times to valid face and car trials at 100ms and 800ms were tested for normality. Histograms and QQ plots showed that these variables were normally distributed, apart from a slight positive skew to the reaction time data for the 800ms Car variable. The Shapiro-Wilk test confirmed that all variables were normally distributed with the exception of reaction times to valid car stimuli at 800ms, W = .95, p = .05. However, ANOVAs are known to be robust to violations of the assumption of normality (Schmider et al., 2010), therefore parametric testing of the reaction time scores for valid trials was carried out without transformation. None of these four reaction time variables were found to have any outlying data points, indicated by Z scores greater than 3.29, that may affect subsequent analyses.

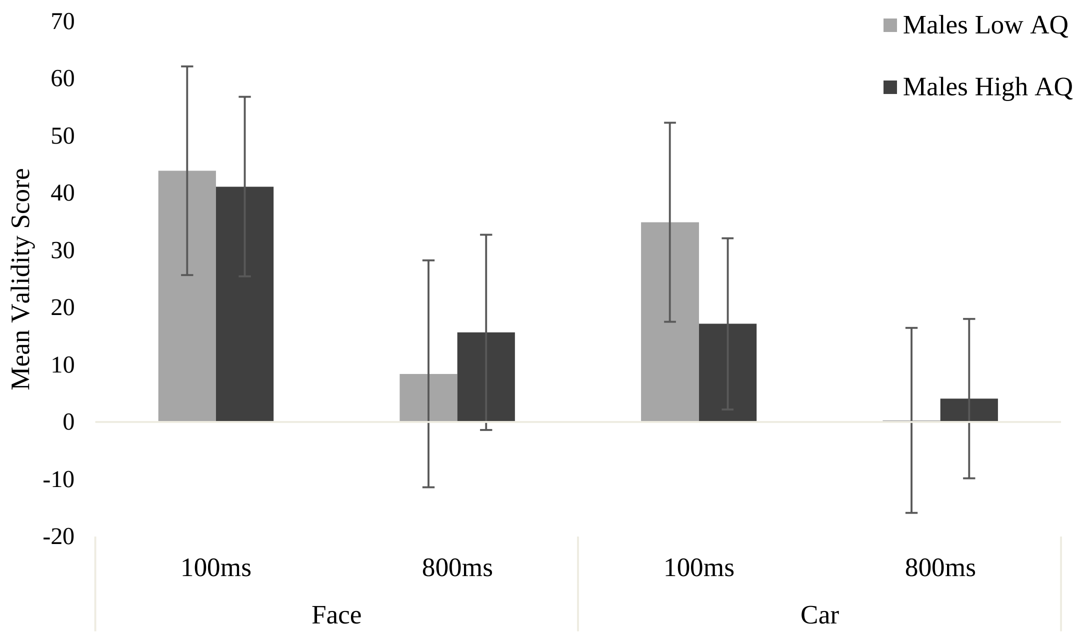
The four Validity Scores were also tested for normality. All Validity scores were found to approximately follow a normal distribution in QQ plots and histograms, and the Shapiro-Wilk test for normality confirmed that all validity scores were normally distributed (for faces at 100ms W = .98, p = .25; for faces at 800ms W = .99, p = .75; for cars at 100ms W = .98, p = .17; for cars at 800ms W = .99, p = .65). Testing for outliers, the 100 car bias was found to have one outlying data point with a Z score greater than 3.29. The analysis was performed with and without this participant and this outlying data point was not found to be influential on the analysis as the results of the ANOVA were unchanged (see Appendix III).

Social anxiety was measured as higher levels have been reported to produce attention biases both towards and away from faces (Chen et al., 2002; Garner et al., 2006), and to be related to autism traits (White et al., 2012). LSAS scores were found to significantly differ between High and Low AQ groups in this sample, *t*(92) = -4.14, *p* < .001. Pearson's correlations were carried out between LSAS scores and the Validity Scores relating to faces to test if LSAS might be related to attentional disengagement to faces or objects. As in chapter 4, the LSAS was not correlated with any of the Validity Scores relating to faces for High (for Faces at 100ms, *r*(49) = .15, *p* = .29; for faces at 800ms, *r*(49) = .-.01, *p* = .95) or Low AQ groups (for Faces at 100ms, *r*(45) = -.02, *p* = .91; for faces at 800ms, *r*(45) = .05, *p* = .74), or across all participants, for faces at 100ms, *r*(94) = .09, *p* = .37 and for faces at 800ms, *r*(94) = .06, *p* = .55. This shows no relationship between LSAS and attention biases with the stimulus cues across any of the different times.

Analysis

Validity scores based on response latencies were the main dependent variable for the study. A Group (Low AQ vs High AQ) x Sex (male vs female) x Cue Type (Face vs Car) x Time (100ms vs 800ms) ANOVA was performed on Validity Sores. A significant main effect of Cue Type was revealed, *F*(1, 90) = 17.62, *p* < .001, η_p^2 = .164, with Validity Scores being greater for face stimuli (mean = 18.97) than for cars (mean = 7.92). There was also a main effect of Time, *F*(1, 90) = 37.09, *p* < .001, η_p^2 = .292, with Validity Scores being greater when stimuli were presented for 100ms (mean = 28.27) than 800ms (mean = -1.39). There was a further main effect of Sex, *F*(1, 90) = 6.76, *p* = .011, η_p^2 = .070, with Validity Scores being greater for males (mean = 20.68) than females (mean = 6.21). The main effect of Group was not significant, *F*(1, 90) = 0.23, *p* = .63, η_p^2 = .003. Crucially for the present study, there was no significant interaction between Group and any other variables (See Figure 5.2; Cue x Group interaction: *F*(1, 90) = 1.29, *p* = .26, η_p^2 = .014; Cue x Time x Group: *F*(1, 90) = 0.03, *p* = .86, η_p^2 < .001; Cue x Group x Sex: *F*(1, 90) = 0.38, *p* = .54, η_p^2 = .004; Cue x Time x Group x Sex: *F*(1, 90) = 0.63, *p* = .43, η_p^2 = .007). No interactions between other variables were significant.

a)



b)

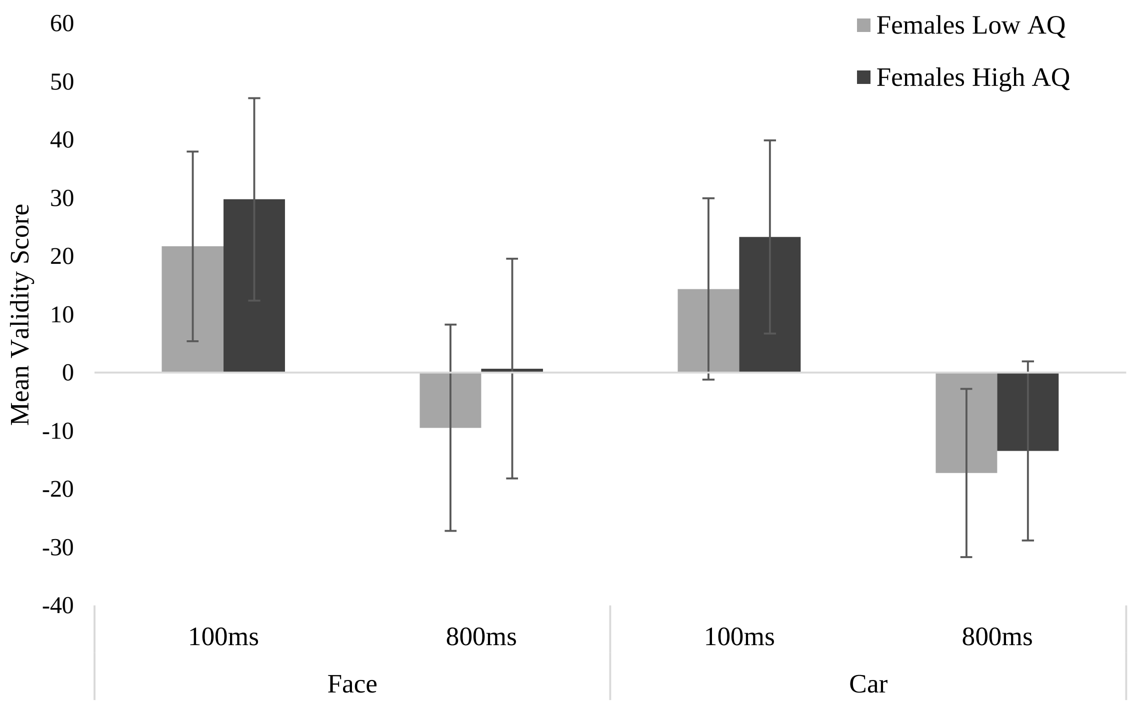


Figure 5.2. Mean Validity Scores for Low and High AQ groups for a) males and b) females for faces and cars at 100ms and 800ms presentation times. Error bars show 95% confidence intervals of the mean.

To explore whether there were any differences in the initial orienting of attention, the reaction times to valid trials were entered into a Cue x Time x Group x Sex ANOVA. There was a significant main effect of Cue, $F(1, 90) = 48.15$, $p < .001$, $\eta_p^2 = .349$, with reaction times to valid face cues being faster (m = 535ms) than to valid car cues (m = 545ms). Additionally, there was a significant main effect of Sex, $F(1, 90) = 8.25$, $p = .005$, $\eta_p^2 = .084$, with males having faster reaction times to valid cues (m = 521ms) than females (m = 559). No other main effects or interactions approached significance, all F's < 2.7, all p's > .10. This shows that males were faster to initially orient attention to cues than females, as well as being slower to disengage attention, and that all participants were faster to initially orient to face cues as well as being slower to disengage from them.

Houses were used in the present study as filler trials. To explore whether there were any group differences in attention to these, independent samples t-tests were carried out on validity scores for house cues at 100ms and 800ms. Independent samples t-tests revealed there was no significant difference between groups in either Validity scores of Houses at 100ms, $t(92) = -1.03$, $p = .31$, or of Houses at 800ms, $t(92) = -1.54$, $p = .13$. Furthermore, adding houses into the main ANOVA, resulting in a Cue Type (faces, cars or houses) by Time (100ms or 800ms) by Sex (male or female) by AQ Group (Low or High AQ) mixed ANOVA, revealed no difference to the results of the ANOVA presented above without Validity Scores for Houses included (main effects of Cue, $F(2, 180) = 9.41$, $p < .001$, $\eta_p^2 = .095$, Time, $F(1, 90) = 41.95$, $p < .001$, $\eta_p^2 = .318$, and Sex, $F(1, 90) = 6.98$, $p = .010$, $\eta_p^2 = .072$, with all other main effects and interactions non-significant, all F's < 1.54, all p's > .21). The main effect of Cue Type revealed that validity scores were significantly greater for all participants when the cue was a face compared to when it was a car, $t(91) = 3.23$, $p = .002$, or a house, $t(91) = 2.91$, $p = .005$. There was no significant difference between Validity Scores for car cues and house cues, $t(91) = -0.37$, $p = .711$. The main effect of Time, as above, revealed that Validity Scores were greater when stimuli were presented for 100ms (m = 26.46) compared to 800ms (m = -2.38). Finally, the main effect of Sex also remained unchanged with males displaying greater validity scores (m = 19.31) than females (m = 4.77). This therefore supports the exclusion of houses within the main analysis for the present experiment as they were not of experimental interest and their inclusion did not alter the findings.

Discussion

This experiment investigated the disengagement of attention from faces or mechanical objects in relation to subclinical autism traits. Slower disengagement from faces relative to cars was found across all participants. No differences were found between participants with low and high levels of autism traits in disengaging attention in general, or in relation to disengaging attention from faces or cars. It was also found that males were faster to orient and slower to disengage attention than females, and briefly presented cues resulted in longer disengagement latencies than cues with longer presentation times.

It was predicted that the low autism trait group would show slower disengagement from face stimuli than the high autism trait group, however all participants were found to show slowed disengagement of attention from faces relative to cars. The disengagement of attention is under top down control and as such is reflective of reward, threat, or long term importance of the stimuli (Desimone & Duncan, 1995; Theeuwes & Belopolsky, 2012). This suggests that the face images were more salient than car images to participants with both high and low levels of autism traits, and suggests typical social attention patterns in those with high levels of autism traits. Therefore it appears that differences in disengaging attention from faces found in young children with ASD relative to typically developing controls (Chawarska et al., 2010; Kikuchi et al., 2011) are not related to the subclinical spectrum. However, it should be noted that the present study investigated adults who have a great deal more experience with the social world than young children. Therefore, there may be differences in disengaging attention from faces in children with high levels of subclinical autism traits that are no longer present in adults as they have more experience of the learnt importance of faces.

Alternatively, it is possible that the 100ms display time was too short to uncover attentional disengagement differences in relation to different cues and subclinical autism traits. Fox et al. (2001) found no group difference in disengaging from attention to angry faces between those high and low in anxiety on a peripheral cueing task when cues were displayed for 100ms, but a difference was found between groups when cues were displayed for 250ms. Therefore the 100ms cue duration in the present study could have been too quick for differences in disengaging in relation to neutral faces to emerge. Whilst 100ms may be fast enough to detect a face, it may not be long enough to elicit the top down attentional control which modulates the disengagement of attention (Theeuwes & Belopolsky, 2012). Top down influences on attention are thought to become engaged from approximately 100ms (Connor et al., 2004), and therefore this stimulus presentation time was on the cusp of the onset on top down influences. A slightly longer presentation time of 200ms might reflect group differences in how long top down processes remain engaged with each type of stimuli. Additionally, the 800ms cue may have been too long as there were no group differences in disengaging attention from faces or cars at this presentation duration either.

Disengagement latencies were found to be longer when stimuli were presented for 100ms than 800ms. The presentation duration of 800ms was selected as previous research has found that individuals with ASD may take longer to orient their attention to peripheral cues (Townsend, Harris, et al., 1996; Wainwright & Bryson, 1996). Therefore the duration of 800ms was included to capture differences in disengagement of attention that may not have emerged at 100ms because of a slower movement of attention to attend the cue in the first instance. However, greater cueing effects would be expected at 100ms than 800ms as inhibition of return (IOR) can inhibit target detection at the cued location when cues are displayed for longer than around 300ms (Klein, 2000). Indeed inhibition of return, whereby cognitive resources are preferentially allocated to a novel location rather than a previously attended location, is likely to account for the negative mean validity score found when stimuli were presented for 800ms. The negative validity score indicates that participants were responding faster when the target was invalidly cued compared to when it was validly cued. Perhaps, therefore, the use of an 800ms cue was too long to expect facilitative effects of a valid cue from a typically developed population high in autism traits but below a clinical threshold. However, the use of this cue presentation duration remains justified to explore attentional differences which may be uncovered after longer durations as some research has shown that ASD is associated with a delay in attending to peripheral cues. Townsend, Harris, et al. (1996) found that participants with ASD did not show a difference in reaction times between valid and invalid cues at 100ms but did when cues were presented for 800ms. However, it may be useful in exploring the time frame of attentional disengagement from faces and objects of circumscribed interest in sub clinical autism traits to use slightly shorter presentation durations in future research.

As previous research has conflicted in relation to an impairment of disengaging attention in ASD (e.g. Landry and Bryson, 2004, vs Fischer et al, 2013), and difficulty disengaging attention has been found in infants in the BAP (Elsabbagh, Volein, Holmboe, et al., 2009), the present study also aimed to investigate general disengagement differences between those with high and low levels of autism traits. There was no group difference in the ability to disengage attention between those with low and high levels of autism traits. It is likely that no difference was found because the participants used in the present study were adults, whereas the majority of research which has found differences in the disengagement of attention in relation to ASD or the sub clinical spectrum of autism traits has involved infants or children (Elsabbagh, Volein, Holmboe, et al., 2009; Landry & Bryson, 2004). The majority of studies which find slower attentional disengagement in children with ASD, the BAP, or children who go on to develop ASD, involve young children aged approximately in the range of 12-14 months (Bedford et al., 2014; Elsabbagh et al., 2013; Elsabbagh, Volein, Holmboe, et al., 2009; Zwaigenbaum et al., 2005). However, studies which find no group differences in disengagement abilities between ASD and control participants tend to involve older children (Fischer et al., 2013 mean age = 9.2 years; Iarocci & Burack, 2004, mean age = 11.6 years). However, Landry and Bryson (2004) used a gap-overlap task and found that even older children (mean age = 5.6 years) demonstrated longer disengagement latencies than matched control children. This suggests that differences may still be present in slightly older children and so disengagement differences in ASD are not necessarily a result of the age of participants. Another factor that could be implicated in disengagement difficulties in relation to the autism spectrum is IQ. The mean non-verbal IQ for children with ASD in Landry and Bryson's (2004) study was 70.2, while the IQ's reported in Fischer et al. (2013) were108.8. The much lower IQ could potentially explain why differences in disengaging attention were found by Landry and Bryson (2004), but not Fischer et al. (2013). The present study involved adults of working age who were all either employed by or studying at the University of Bath. Therefore they are likely to be of average to above average intelligence. Therefore, given the characteristics of the present sample, it appears that difficulties disengaging attention are not related to subclinical autism traits in adults of average intelligence, and this is a similar pattern seen in older children with a diagnosis of ASD and average to above average intelligence.

Male participants were found to be faster to orient attention to valid cues, and slower to disengage attention from invalid cues, a result that was not anticipated. This therefore suggests that males were more influenced by the cues than the female participants. The cues in the present study were predictive, with a cue validly indicating where a target will appear in two thirds of trials. Therefore it is beneficial for task completion to attend to the cues. Previous research has found no differences in orienting or disengaging attention to or from peripheral cues between males and females (Bayliss et al., 2005; Merritt et al., 2007). However the peripheral cueing tasks within these papers used non-predictive cues, i.e. they were valid 50% of the time and invalid 50% of the time, rendering them irrelevant to target detection. Bayliss et al. (2005) did find that females were more influenced by non-predictive central cues than men leading the authors to conclude that females are more influenced by irrelevant cues. Stoet (2009) corroborated this finding with a Go/No-Go task where participants had to respond to peripheral stimuli. Again females were more influenced by irrelevant information than males. The authors argue that this may be because males tend to focus more on specific, task relevant information. This explanation may account for the results of the present study as it seems that the males were more focused on the cues, which were relevant, than the females.

Reaction times were found to be faster to a valid face cue than a valid car cue across all participants. This is indicative of faster orienting of attention towards faces than cars. Faster orienting towards the face cues was to be expected owing to the prominence of social information (Johnson, Dziurawiec, et al., 1991; Tomalski et al., 2009). This supports the result from the dot probe experiment in Chapter 4 whereby faces were also found to capture attention to a greater extent than cars. However, Chapter 4 found differences in the rapid orienting of attention in relation to subclinical autism traits in males. In the present study, all participants were found to orient faster to face cues than car cues, including when faces were presented very rapidly at 100ms. The findings from the present chapter relating to orienting attention and those from Chapter 4 appear contradictory but the dot probe and peripheral cueing experiments measure attention under different conditions. In the dot probe, attention must be selectively engaged on one of two stimuli and therefore it measures the extent to which faces capture selective attention. In the peripheral cueing task, the exogenous onset of the peripheral cue automatically captures attention meaning therefore that the face is mandatorily attended to. Therefore when orienting to a face is under volitional control, there may be differences in relation to subclinical autism traits, but when faces are mandatorily capturing attention, they are processed immediately and elicit faster orienting than other objects.

Once again there is a potential limitation in that both the face and car stimuli were rated as less positive in valence than the house stimuli. However, the house trials were used as filler trials in the present experiment and therefore not included in the analysis. Only faces and cars were compared, and these two categories of stimuli were not found to differ on the dimensions of valence, complexity or interest. Therefore if the negative valence of the face stimuli was causing the faster orienting and slowed disengaging of attention, it would be expected that cars would also elicit the same pattern of attention. This was not found to be the case therefore it is unlikely that the negative valence of the stimuli had an adverse impact on the results of the present study.

It is worth noting that participants were not asked to indicate whether they were aware that the study was exploring attention towards the faces and cars specifically. Therefore it is not clear that houses successfully achieved the goal of consisting of innocuous filler trials, however, the addition of the houses to the main analysis was not found to alter results. This goes some way to suggesting that the house stimuli were incidental to the main aims of the research, although it would be worth asking participants of their awareness of the aims of the study in future research.

In conclusion, faces were found to elicit faster orienting of attention towards them and slower disengagement from them across all participants, regardless of levels of autism traits. This suggests that faces, when presented in isolation and exogenously cued, are highly salient for adults from the general population with subclinical levels of autism traits. Therefore, the lack of an attention holding effect of faces seen in young children with ASD (e.g. Chawarska et al., 2010; Kikuchi et al., 2011) is not represented in adults in the subclinical spectrum of autism traits. There was no evidence to suggest a general difficulty in disengaging attention in relation to subclinical autism traits. Additionally it was found that males were faster to orient attention to cues and slower to disengage attention from them, suggesting an increased reliance on the informative cues in the present task relative to females.

Chapter 6

Attention to Social and Mechanical Objects in Natural Scenes in Subclinical Autism Traits

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Chapter Abstract: Chapters 4 and 5 used controlled experimental reaction time methods to explore the orienting and disengaging of attention. The present study augments these by utilising a more ecologically valid method by tracking participants' looking behaviour during free viewing of natural scenes. It was found that higher AQ scores were associated with less time spent fixating on social elements of scenes, and more time fixating on the background of scenes. There was a non-significant trend for higher AQ scores to be associated with shorter fixations on social elements of scenes, suggesting that higher levels of autism traits are related to faster disengaging from social information than lower levels. No relationship between autism traits and the time taken to fixate on social or mechanical objects was found, and all participants were faster to fixate on social elements of scenes. This suggests that subclinical autism traits are related to a reduction in overall top down modulation of attention to social information, but not in the tendency to rapidly orient to social information within natural scenes.

The use of eye tracking technology in individuals with ASD has illuminated atypical patterns of visual attention compared to typically developing controls (Guillon et al., 2014). Riby and Hancock (2009a) presented individuals with ASD, William's syndrome and typically developing controls with images of natural scenes containing embedded faces out of context. They found that those with ASD spent the least time of all groups fixating on the faces. The authors argue that this was due to a lack of interest in social information in the participants with ASD. People with ASD have also been found to spend less time than controls fixating on the eye region of the face and to look more at other objects in scenes than people (e.g. Klin et al., 2002).

However, not all eye tracking research finds differences in social attention in ASD. Freeth et al. (2010) have used more naturalistic stimuli than the embedded faces used by Riby and Hancock (2009) and other studies which have presented faces in isolation (e.g. Dalton et al., 2005). Participants viewed scenes depicting a person in an everyday setting, such as in an office, and eye tracking revealed that ASD and control participants spent a similar amount of time fixating people's faces (Freeth et al., 2010). This suggests that attention to social information may be typical in ASD when such information is presented in a natural context. However, Riby and Hancock (2008) used photographs of actors engaged in natural activities to explore the extent to which individuals with ASD and William's Syndrome look at people and faces within natural scenes. It was found that participants with ASD spent less time than typically developing control participants fixating people and faces. Therefore, this suggests that social attention is atypical in ASD.

Guillon et al. (2014) reviewed eye tracking research investigating diminished social attention in autism. In research with older children, adolescents or adults, five studies found evidence for a reduction in social attention in ASD, three reported mixed findings, and four studies found comparable attention to social information between ASD and control participants. This highlights the conflicting research findings regarding social attention in ASD. Hanley et al. (2013) attempted to shed light on why there might be such variability in the results of eye tracking studies on social attention in ASD. They compared visual attention to scenes that were natural (photographs of naturally occurring social interactions) or acted (stills from a TV show). These either contained a face in isolation or social scenes containing two people. The group with AS demonstrated typical face viewing patterns when the faces were presented in isolation, but in the more complex social scenes the AS group spent less time looking at the eye region than the typically developing control group. This effect was more pronounced in the natural scenes than the acted scenes suggesting ecological validity plays an important role in social attention in ASD. The authors suggest that social attention is typical when viewing a face in isolation as there is no competition for attentional resources, but when there is more information in the visual scene, the eyes, the most socially relevant part of a face, are not prioritised in ASD the same way they are in typical development.

Some argue that looking for categorical differences in looking behaviour between those with ASD and those without misses out on subtler relationships between the diminished social skill in ASD and visual attention to social information. Parish-Morris et al. (2013) suggest that the face processing skills of emotion discrimination and person identification lie on a continuum, rather than there being categorical differences between those with ASD and those without. Using eye tracking whilst viewing social and non-social images, they found no group differences between the ASD and control groups for visual attention to faces relative to objects but instead found that longer looking times to faces were related to improved ability on the face processing tasks regardless of diagnostic group. The authors suggest that these dimensions span both typically developing individuals and individuals with ASD. As such, this suggests that exploring social attention in relation to the subclinical autism spectrum may help to illuminate differences in ASD as visual attention differences may follow a spectrum of social ability.

In the subclinical autism spectrum, differences in social attention have been illustrated using eye tracking technology. Swanson, Serlin, and Siller (2013) measured the extent to which children displayed the BAP via parent completion of the SRS (Constantino et al., 2003), and assessed children’s joint attention ability using eye tracking. The stimuli consisted of a face presented in the centre of the screen which moved to look towards one of the four corners of the screen where a target appeared either congruently with the gaze direction or incongruently. It was found that children who scored highly on the SRS did not differ in their allocation of gaze towards the face or target, whether the eye gaze of the face was congruent or incongruent with the target location. Those with low SRS scores spent more time fixating on the target in the congruent condition and more time fixating on the face in the incongruent condition. This suggests that subclinical autism traits are associated with a reduction in following joint attention in children. The same experimental method was completed by adult college students with autism traits measured by the Broad Autism Phenotype Questionnaire (BAPQ; Swanson & Siller, 2014). Again, adults scoring highly on the BAPQ did not modulate their gaze behaviour in relation to where the central face was looking. It is suggested that people with low scores on the BAPQ are more likely to be influenced in their gaze behaviour by joint attention. Swanson and Siller (2014) measured gaze following tendencies which is not directly comparable to general visual attention to social versus non-social objects which the present study is exploring. However, it does suggest that there are differences in social processing in relation to subclinical autism traits that manifest in differences in looking behaviour. Therefore, it is highly plausible that there may be general differences in the allocation of visual attention to social information between individuals with low levels of autism traits and high levels.

Freeth et al. (2013) found that adults with higher levels of autism traits, as measured by the AQ, spent less time looking at an actor in a pre-recorded video interview than those who scored lower on the AQ. Interestingly this pattern was not observed when the interviewer was present in the room and the authors suggest that this may be because social information is more salient when another person is present. As the present study uses images presented on a computer screen, it would be expected that a similar pattern of results might be found to the video condition in Freeth et al. (2013). Similarly, Chen and Yoon (2011) found that typically developed adult participants who scored highly on four sub scales of the AQ (one subscale omitted due to time constraints, author correspondence) spent less time fixating on the eye region of faces in videos where the actor displayed direct gaze than participants with low AQ scores. Again this shows that differences in social attention are manifested in relation to subclinical autism traits in a similar way to the more established findings in relation to atypical visual social attention in ASD.

Researchers are beginning to investigate the impact of objects which may be of CI to people with ASD on social attention (Sasson & Touchstone, 2013; Sasson et al., 2008). As outlined in previous chapters, certain topics, such as machines, vehicles and computers, have been identified as being of particular interest to persons with autism in relation to restricted interests and repetitive behaviours (Baron-Cohen & Wheelwright, 1999; South et al., 2005; Turner-Brown et al., 2011). Sasson and Touchstone (2013) found that children with ASD spent less time looking at faces only when they were presented with an object of CI (categories of CI included vehicles, trains and airplanes). This suggests that an increase in visual attention to objects of CI may adversely affect a person's opportunities to learn about the social world as it results in a reduction in attention to social information. This may be due to reduced Social Motivation in ASD (Chevallier et al., 2012) and increased motivation to attend to CI objects. The present study builds on this methodology by using images taken of real life situations containing social elements and mechanical elements as a category of CI in ASD rather than artificially pairing an isolated face and an isolated object.

As yet, no studies have compared looking behaviour to social objects and objects of CI in ASD in natural scenes in relation to sub clinical autism traits, however one study suggests that attention to non-social objects may be atypical in the BAP. In an experiment where an object and a caregiver were positioned equidistant from an infant, Bhat, Galloway, and Landa (2010) found that infant siblings (age 6 months) of a child with autism spent less time looking at their caregiver and more time looking at non-social objects than infants at low risk for ASD when the caregiver was not initiating interaction. This suggests that those at risk of autism, or with the BAP, voluntarily attend more to objects than people. Exploring whether subclinical autism traits are related to differences in overt visual attention to social and mechanical objects will help to illuminate differences and similarities between those who exhibit high levels of autistic traits but do not require a clinical diagnosis, and those who have a diagnosis of ASD.

In line with the present series of experiments' investigation into attention to objects which may be of CI in autism as predicted by the EMB theory of autism (Baron-Cohen, 2002), the present experiment used social and mechanical objects to explore patterns of visual attention in relation to subclinical autism traits. The choice of mechanical objects in the present study included trains, vehicles, planes and computer equipment. This is similar to the object groups selected by Sasson et al (2008) who used trains, vehicles, planes, blocks, home electronics, computer equipment, road signs and sporting equipment for their high-autism-interest category, which have previously been identified as being reasonably common areas of CI in individuals with ASD (e.g. Baron-Cohen, 2002; Baron-Cohen, Golan, Chapman, & Grander, 2007; South et al., 2005; Turner-Brown et al., 2011).

The present study uses three eye tracking measures to explore overt visual attention to social and mechanical objects within natural scenes. The first variable of interest is the overall amount of time spent fixating on each element of the scenes. This is a standard measure in eye tracking research (e.g. Fletcher-Watson et al., 2009; Riby & Hancock, 2008) and illuminates where people's attention is selectively guided under top down control. The second variable that was measured was the latency to first fixations in each area of interest. A participant's first fixation within a scene is an indicator of where their attention is immediately drawn to when they look at the scene, and therefore which element is most salient to them. This offers a natural measure of selective attention orienting that was measured in a more controlled way in the dot probe task in chapter 4. The third variable of interest is the mean duration of each fixation made in each area of interest. This indicates how long the social and mechanical elements of scenes hold the attention of participants. This measure therefore relates to the disengagement of attention (Sasson et al., 2008).

The aim of the present study was to explore looking preferences towards social and mechanical objects in natural scenes in relation to autism traits. It was hypothesised that those with lower levels of autism traits would show greater initial orienting towards social items in the scenes than participants with higher levels of autism traits, evidenced by faster first fixations on social elements of the scenes. It was predicted that those with higher levels of autism traits would be faster to disengage attention from the social elements of scenes, and slower to disengage attention from the mechanical elements of scenes than participants with low levels of autism traits, as evidenced by the duration of each fixation on social and mechanical objects in the scenes. Finally, in line with previous eye tracking research (Freeth et al., 2013; Sasson & Touchstone, 2013; Swanson & Siller, 2014) and the EMB theory of autism, it was hypothesised that those with greater levels of autism traits would spend less time fixating on social elements within scenes, and more time fixating on mechanical elements of scenes than those with low levels of autism traits.

Method

Participants

Participants comprised of forty psychology undergraduate students recruited through the University of Bath Psychology Department Research Participation Scheme to participate in this study in exchange for course credit (see Table 6.1 for demographic information). Thirty six participants identified their ethnicity as White European, 3 as Chinese, and one white and Asian. All had normal or corrected to normal vision, and none reported having any psychiatric diagnoses. Participants were grouped into the 14 Highest and Lowest AQ scorers for analysis (see results section below for more information). There was no significant difference in mean age of the high and low AQ groups, $t(26) = -0.78$, $p = .443$, or in LSAS scores, $t(26) = 0.26$, $p = .794$. The high AQ group had significantly higher AQ scores than the low AQ group, $t(26) = -10.30$, $p < .001$. A chi square test showed that the distribution of males and females across the high and low AQ groups differed to what would be expected given the number of males and females overall, $\chi^2(1, N = 28) = 6.09$, $p = .014$.

Table 6.1. *Demographic information and mean questionnaire scores for the sample as originally recruited, the High and Low AQ groups as used in analysis, and the overall sample retained in the analysis.*

	Original Sample	Low AQ	High AQ	Overall for Sample Analysed
N	40	14	14	28
Males: Females	11:29	0:14	5:9	5:23
Mean Age (*SD*)	18.78 (0.66)	18.71 (0.73)	18.93 (0.73)	18.82 (0.72)
Mean Total AQ (*SD*)	13.78 (5.28)	8.50 (2.10)	18.93 (3.15)	13.71 (5.92)
Mean Total LSAS (*SD*)	37.73 (17.23)	36.21 (17.62)	34.64 (13.56)	35.43 (15.45)

Materials

Fifteen scenes of everyday life containing a social and a mechanical element were presented to participants. Ten of the images were taken with a Canon EOS 350D digital camera of naturally occurring scenes from around Bath, and five similar images were downloaded from public domain websites. The social elements within each scene contained variability in terms the social content in order to represent natural social images. There were seven scenes containing one person, and eight scenes containing two or more people. In the majority of scenes the people were going about their business without looking at the camera. The mechanical element within each scene was one large machine and this category incorporated objects with a mechanical function, including electrical equipment.

Areas of Interest (AOIs) were created within each scene using ASL Results Plus, so the eye tracker could record fixation time in those areas. The AOI's for social and mechanical elements were matched with each other in terms of area within each scene, and the photographs had been taken with the intention of matching sizes of AOIs. The AOIs allowed for at least 1° of visual angle in error around the object of interest in accordance with the ASL D6 error rate, except in cases where a background object of salience/high contrast fell within that range (e.g. a green and white sign; an orange and white traffic cone) or where it would cause the two AOIs to overlap (see figure 6.1 for an example of social and mechanical AOIs). The average size of the AOIs for both social and mechanical was 232.96cm^2 taking up approximately 20% of the screen each.

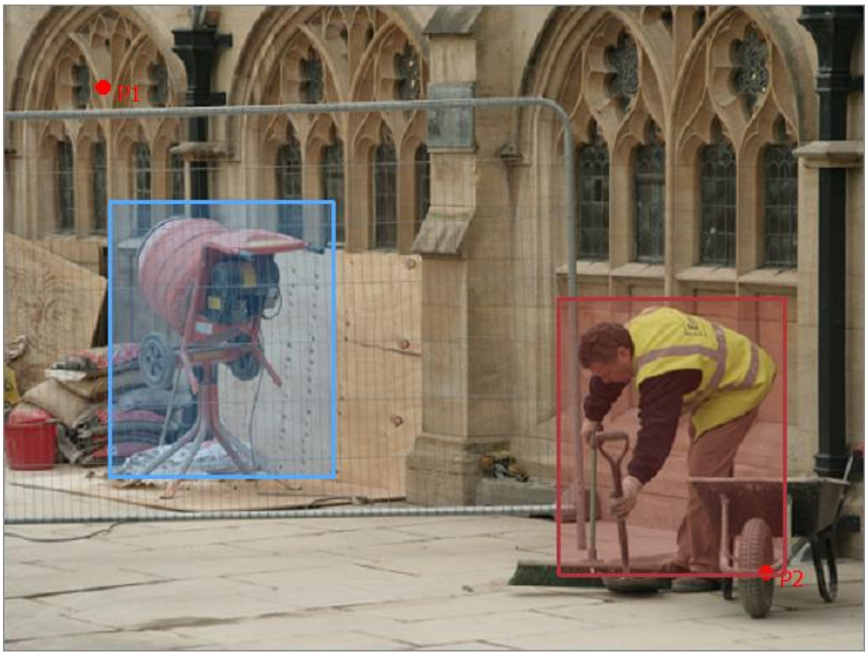

Figure 6.1. Example of social (red) and mechanical (blue) AOIs

The scenes included were: a bus and people waiting at the bus stop; a cement mixer and workman; a coffee machine and barista in a cafe; a jet ski and a couple walking down the beach; a dump truck and workmen on a building site; a computer and office worker; a photocopier and a person using it; a sewing machine and a girl using it; a tractor and people sitting on a bench nearby; a phone box and people in the street; a cash machine and man sitting on a wall; a child and bicycle toy; an aeroplane and people waiting to board; a train with people standing outside; and a car and people crossing the road. The scenes were presented so as to fill the entire 19 inch monitor (aspect ratio 4:3), and were set to dimensions of 640 x 480 pixels.

Participants also completed the AQ (Baron-Cohen, Wheelwright, Skinner, et al., 2001) to measure self-reported autism traits, and the LSAS (Baker et al., 2002) to measure self-reported social anxiety, as described in the materials section of Chapter 4. As in chapters 4 and 5, social anxiety was measured to test its relationship to social attention as social anxiety which has been found to correlate to AQ scores (White et al., 2011).

Procedure

Participants were tested individually in a small research laboratory at the University of Bath. Before the experiment began, the eye tracker was calibrated for each participant using a 9 point procedure, where participants looked sequentially at 9 points in rows of 3 x 3 on the screen and the eye tracker recorded the location of their pupil and cornea. Calibration was repeated until successful, or testing was terminated if calibration was repeatedly unsuccessful. Participants were informed not to move their head once calibration was complete. In cases where this did happen, the calibration procedure was repeated.

The 15 scenes were presented on a monitor with the centre of the screen situated approximately 57cm directly in front of the participants' eyes. The stimuli were presented using E-Prime. An ASL D6 eye tracking camera, which tracks eye movements through corneal reflection, and its corresponding software package were operated from a separate computer to record eye movements. The camera was placed just below the monitor display.

At the start of the experiment, Participants were initially presented with instructions on screen asking them to look at the scenes as naturally as possible. The experimenter then initiated the presentation of scenes. A central fixation cross was presented for 300ms between each image to reorient attention to the centre of the image and to ensure visual exploration began from the same point for each participant. This was followed by the presentation of the 15 scenes for 5 seconds each where eye gaze was recorded. Scenes were presented in the same order to all participants.

After completing the eye tracking task, participants then completed the AQ and LSAS so that the content of the questionnaires would not impact on their natural looking behaviour. The entire process took approximately 15 minutes.

Results

Data Preparation

Fixations were calculated by ASL Results Plus with the threshold criteria of gaze remaining within one degree of visual angle of the point of gaze, and a minimum fixation duration of 100ms (seven eye tracker samples). Fixations were ended by three eye tracker samples outside this threshold. The maximum allowed pupil loss for fixations was 200ms (13 eye tracker samples).

One scene was excluded from analysis owing to an error in the eye tracking data processing software which was unable to parse the final event in the sequence meaning that the fixations on the fixation cross shown prior to the train scene were included within that scene's data. This meant that results were analysed using only 14 scenes.

Data from trials where data was collected for less than 50% of the time due to blinks or head movements were discarded. This resulted in all data for one participant being discarded as four out of fourteen trials recorded included less than 50% of data. In addition, the mean amount of data collected for remaining trials for this participant was 63.14% which was much lower than any other participant (next lowest 82.06%), and the group mean of 92.80%. Viewing the video recording of the participant's eye and the video showing the recorded point of gaze presented over the scenes confirmed that this was indicative of the eye tracker losing calibration throughout the experiment rather than a result of naturally occurring blinks. A further one trial was removed for each of five other participants. Altogether excluded trials accounted for 3.39% of trials.

Three dependent variables were included to explore the impact of autism traits on visual attention to social and mechanical objects: the length of total fixation time spent in each AOI, the latency to first fixate in each AOI, and mean duration of each fixation. Each dependent variable was determined for Social and Mechanical AOIs, and outside either AOI, within each scene for each participant by ASL results plus. Fixations beginning within 80ms from the onset of the image were not included in analyses as some report that saccade latencies less than 80ms from the onset of a stimulus are likely to be anticipatory (Findlay & Walker, 1999), and face directed saccades can occur in as little as 100ms (Crouzet et al., 2010). Therefore the first fixation after 80ms from scene onset was used to compute the latency to First Fixation variable. Finally the mean duration of each fixation, in ms, within each type of AOI was computed for all participants.

Total AQ scores and total LSAS scores were both found to be normally distributed, $W(39) = .977$, $p = .612$ and $W(39) = .962$, $p = .202$ respectively. This was supported by histograms and QQ plots. Interestingly, total AQ scores and total LSAS scores were not found to be correlated in the present sample, $r(39) = .03$, $p = .840$. This is likely because of the low levels of autism traits reported by this sample and limited range of AQ scores (mean = 13.78, range = 22. Range for subclinical sample from the general population in Chapter 4 was 32; see below)

Analysis Design

The present experiment was designed to be analysed using high and low autism trait groups using a median split as in the previous two chapters, with sex as a factor. However, due to the participant recruitment process utilising the psychology Research Participation Scheme, the participants were mostly female and scored low on the AQ. AQ scores were lower than would be usually be expected ranging from 4-26 with a mean of 13.78 ($SD = 5.28$). In the original development of the AQ, the mean is given as 16.4 in general (Baron-Cohen, Wheelwright, Skinner, et al., 2001), which has later been updated to 17 (Ruzich et al., 2015), from which the present mean significantly differs, $t(39) = -3.14$, $p = .003$. As the present sample consisted of 72.5% females, the mean AQ was also compared to the mean for females in Baron-Cohen, Wheelwright, Skinner, et al. (2001) which was 15.4. The difference between the mean AQ score of the present sample and the mean AQ score for females in the original study approached significance, $t(39) = -1.94$, $p = .059$. Despite the difference in spread of scores from the original validation of the AQ, the scale still retained acceptable internal consistency, $\alpha = .71$. Comparing sexes and dividing participants into High and Low AQ scorers based on the median of 13 was considered overly artificial. Therefore a decision was made that, rather than to use all participants split at the median, the highest and lowest 14 AQ scorers (to retain a sample size of 28 which was identified by power analyses) would be used to create high and low autism trait groups to ensure real differences in autism trait levels were represented between groups. Scores in the low AQ group ranged from 4-11 (mean = 8.5, *SD* = 2.10), and in the high AQ group from 15-26 (mean = 18.93, *SD* = 3.15). All participants in the low AQ group were female, and in the high AQ group, nine were female and five male.

Social anxiety was not found to relate to any of the dependent variables in the final sample, either as a whole or within the low and high autism trait groups, all *r*’s < .35, all *p*’s > .23.

Dependent Variable 1: Overall Fixation Time

The mean amount of time fixating in the Social and Mechanical AOIs per scene was calculated for each participant. The mean amount of time spent fixating within Social and Mechanical AOIs, and outside either AOI were all found to be normally distributed across participants according to histograms, QQ plots, and the Shapiro Wilks test for normality ($W(39) = .972$, $p = .626$ for Social AOIs; $W(39) = .958$, $p = .315$ for Mechanical AOIs; $W(39) = .955$, $p = .265$ for Outside either AOI). No outlying data points were found (all Z scores < 3.29).

A repeated measures ANOVA with factors of AOI (Social, Mechanical or outside either) and Group (high or low AQ) revealed a significant main effect of AOI, $F(2, 52) = 18.06$, $p < .001$, $\eta_p^2 = .410$. The mean time spent fixating in Social AOIs was 1637ms, 1111ms within Mechanical AOIs, and 1229ms outside either AOI. Paired samples t-tests showed that overall, participants spent more time fixating within Social AOIs than mechanical AOIs, $t(27) = 4.93$, $p < .001$, $d = 0.93$, and outside either AOI, $t(27) = 3.43$, $p = .002$, $d = 0.65$. Additionally, participants spent significantly more time fixating outside either AOI than within Mechanical AOIs, $t(27) = -2.06$, $p = .049$, $d = -0.39$. The main effect of Group was not significant, $F(1, 26) = 0.81$, $p = .375$, $\eta_p^2 = .030$.

The interaction between Group and AOI was found to be significant, $F(2, 52) = 4.75$, $p = .013$, $\eta_p^2 = .154$ (see Figure 6.2).

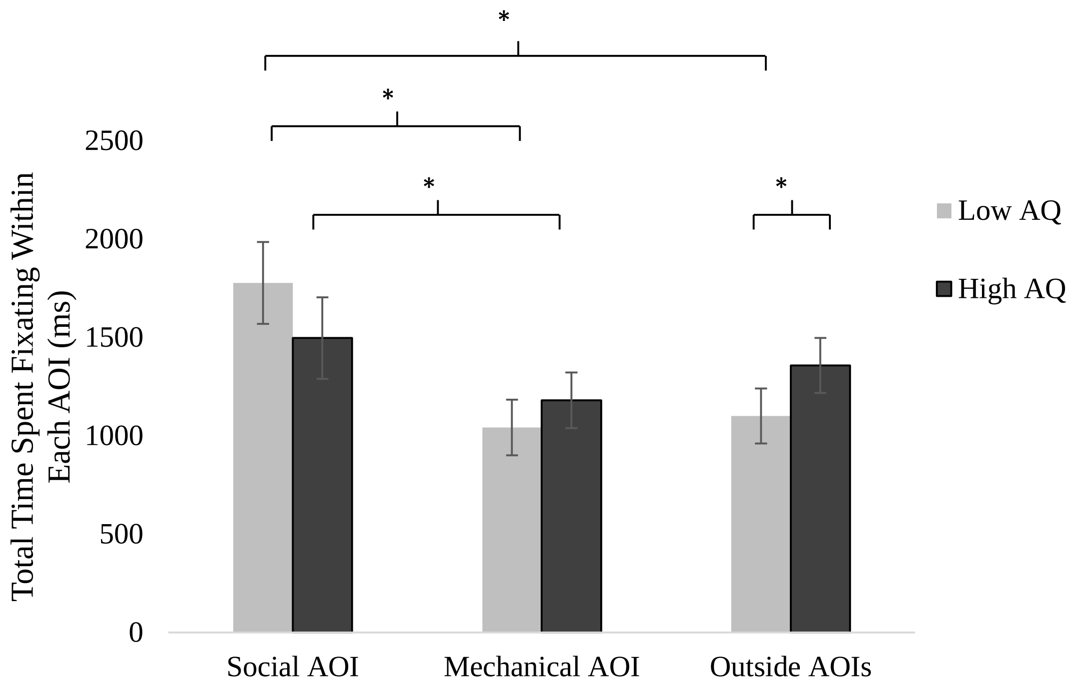

Figure 6.2. Mean time spent fixating within Social and Mechanical AOIs, and outside either AOI, for the high and low AQ groups. Error bars show 95% confidence intervals of the mean. **p* < .05

Independent samples t-tests revealed that the difference in time spent fixating within Social AOIs between low and high AQ groups approached significance, $t(26) = 1.96$, $p = .060$, $d = 0.77$. There was no significant difference between groups in the amount of time spent fixating in Mechanical AOIs, $t(26) = -1.43$, $p = .165$, $d = -0.56$. The high AQ group were found to spend significantly more time fixating outside either AOI than the low AQ group, $t(26) = -2.67$, $p = .013$, $d = -1.05$.

Paired samples t-tests showed that the low AQ group spent significantly more time fixating in Social AOIs than Mechanical AOIs, $t(13) = 4.51$, $p = .001$, $d = 1.21$, as did the high AQ group, $t(13) = 2.68$, $p = .019$, $d = 0.72$. However, whilst the low AQ group also spent significantly more time fixating within the Social AOIs than outside either AOI, $t(13) = 3.88$, $p = .002$, $d = 1.04$, there was no difference in time spent fixating these areas for the high AQ group, $t(13) = 1.06$, $p = .308$, $d = 0.28$. Neither group spent a significantly different amount of time fixating in the Mechanical AOIs or outside either AOI, $t(13) = -1.01$, $p = .333$, $d = -0.27$, for the low AQ group, and $t(13) = -1.80$, $p = .095$, $d = -0.48$, for the high AQ group (see Table 6.2 for means).

Table 6.2. *Mean amount of time (ms) spent fixating within each AOI for Low and High AQ Groups (SD).*

	Low AQ (*n* = 14)	High AQ (*n* = 14)
Social AOI	1777 (430)	1496 (318)
Mechanical AOI	1041 (219)	1181 (291)
Outside AOIs	1101 (279)	1358 (228)

Dependent Variable 2: Latency to First Fixations

To initially explore which areas of the scenes initially captured participants' attention, the proportion of first fixations in each AOI was calculated. This data is not suitable for ANOVA analysis due to the proportions of first fixations in each AOI being highly related to one another. However, the results of t-tests comparing the proportions across groups are shown in Table 6.3 for illustration. It can be seen that for both groups, the largest number of first fixations were within the Social AOIs.

Table 6.3. *Mean percentage of first fixations within each AOI (ms) for Low and High AQ Groups (SD)*

	Low AQ (*n* = 14)	High AQ (*n* = 14)	Comparison Statistics
Social AOI	68.60 (14.44)	66.72 (15.41)	$t(26) = 0.33$, $p = .741$
Mechanical AOI	14.44 (8.49)	18.41 (10.33)	$t(26) = -1.11$, $p = .278$
Outside AOIs	16.96 (9.48)	14.88 (11.37)	$t(26) = 0.53$, $p = .604$

The mean latency to make a first fixation within each AOI and outside either AOI was computed for each participant (See Table 6.3 for means). Histograms, QQ plots and Shapiro Wilk tests for normality revealed that the data for mean latency to make first fixations in Mechanical AOIs and Outside the AOIs was normally distributed, $W(28) = .975$, $p = .709$ and $W(28) = .980$, $p = .856$. However, the mean latency to make first fixations to Social AOIs violated the assumption of normality, $W(28) = .921$, $p = .038$. Observation of the histogram for this variable showed that the data was positively skewed, with a large number of data points showing shorter latencies to first fixations. Therefore, a log transformation was applied to all three levels of the first fixation data. This corrected the deviation from normality of the first fixation time for Social AOIs, $W(28) = .959$, $p = .335$, and normality was retained for both the Mechanical AOIs and Outside the AOIs.

The main ANOVA was run on both the untransformed and transformed data to establish whether the violation of normality impacted on the analysis. The significance of results for main effects and interactions were found to be the same whether the transformed or untransformed data were used. Therefore the untransformed data is presented below and the ANOVA with the transformed data can be found in Appendix IV. No outlying data points were found (all Z scores < 3.29).

Table 6.4. *Mean latency to first fixations within each AOI (ms) for Low and High AQ Groups (SD)*

	Low AQ (n = 14)	High AQ (n = 14)
Social AOI	573 (220)	668 (239)
Mechanical AOI	1760 (564)	1561 (303)
Outside AOIs	2090 (480)	1998 (400)

A repeated measures ANOVA with factors of AOI (Social, Mechanical or outside either) and Group (high or low AQ) performed on the latency to first fixation data revealed a significant main effect of AOI, $F(2, 52) = 131.13$, $p < .001$, $\eta_p^2 = .835$. Paired samples t-tests revealed that participants were faster to first fixate in Social AOIs than Mechanical AOIs, $t(27) = -11.42$, $p < .001$, $d = -2.16$, or Outside either AOI, $t(27) = -14.88$, $p < .001$, $d = -2.81$. Participants were also faster to first fixate within Mechanical AOIs than outside either AOI, $t(27) = -4.37$, $p < .001$, $d = -0.83$.

The main effect of group, $F(1, 26) = 0.40$, $p = .532$, $\eta_p^2 = .015$, and the interaction between Group and AOI, $F(2, 52) = 1.35$, $p = .269$, $\eta_p^2 = .049$ (see Figure 6.3), were not significant. These results support the data presented above regarding proportions of first fixations within each AOI.

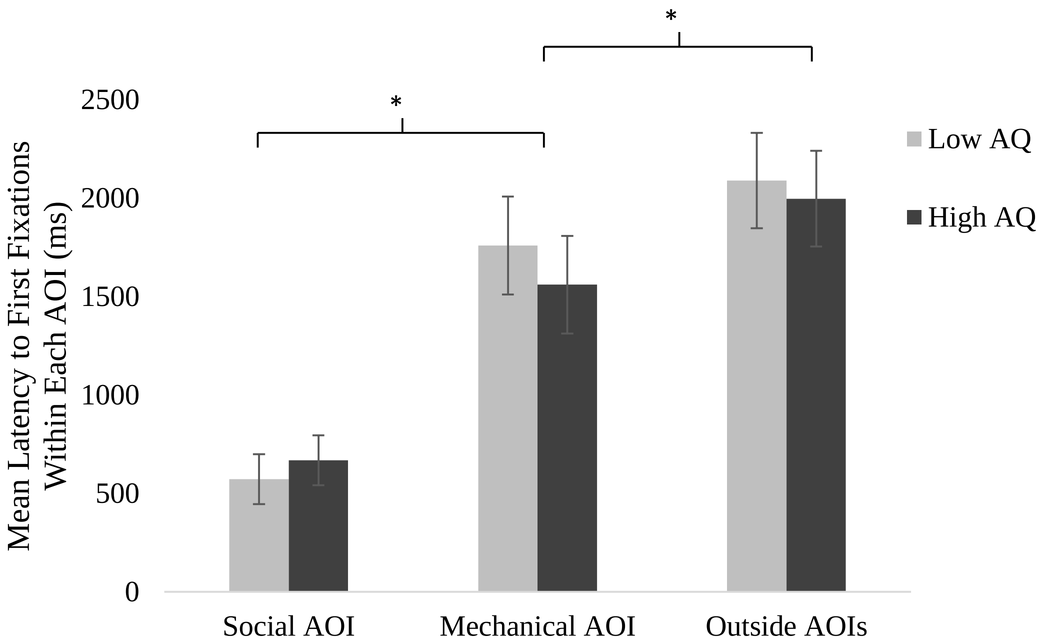

Figure 6.3. Mean latencies to first fixations within Social and Mechanical AOIs, and outside either AOI for low and High AQ groups. Error bars show 95% confidence intervals of the mean. *$p < .05$

Dependent Variable 3: Mean Fixation Duration

The mean duration of each fixation within Social and Mechanical AOIs, and outside either AOI was computed (see Table 6.4 for means). The mean fixation durations within Social AOIs were found to be normally distributed across participants, $W(28) = .941$, $p = .119$. However, the distribution of mean fixation durations in Mechanical, $W(28) = .897$, $p = .010$, and outside the AOIs, $W(28) = .913$, $p = .023$, was found to be non-normal, with histograms indicating that these two variables were positively skewed. Therefore a log transformation was applied to the data. This corrected for normality of distribution for Mechanical AOIs, $W(28) = .937$, $p = .093$, and outside the AOIs, $W(28) = .948$, $p = .176$, and retained normality of distribution for mean fixation durations within social AOIs, $W(28) = .977$, $p = .785$. The main analysis was performed on the transformed and untransformed data and the results were not found to alter. Therefore, the results with untransformed data are presented below for ease of interpretation, and the ANOVA with transformed data can be found in Appendix IV. No outlying data points were found (all Z scores < 3.29).

Table 6.5. *Mean fixation durations within each AOI (ms) for Low and High AQ Groups (SD)*

	Low AQ (n = 14)	High AQ (n = 14)
Social AOI	365 (68)	322 (46)
Mechanical AOI	255 (27)	279 (62)
Outside AOIs	249 (36)	269 (50)

A repeated measures ANOVA with factors of AOI (Social, Mechanical or outside) and Group (low AQ or high AQ) was performed on the mean duration of fixations data. There was a significant main effect of AOI, $F(2, 52) = 38.07$, $p < .001$, $\eta_p^2 = .594$. Paired samples t-tests revealed that participants' fixations were significantly longer within Social AOIs than Mechanical, $t(27) = 5.64$, $p < .001$, $d = 1.07$, and outside the AOIs, $t(27) = 6.68$, $p < .001$, $d = 1.26$. There was no significant difference in the mean duration of fixations within Mechanical AOIs our outside either AOI, $t(27) = 0.98$, $p = .336$, $d = 0.19$. There was no significant main effect of Group, $F(1, 26) = 0.001$, $p = .974$, $\eta_p^2 < .001$. The interaction between AOI and Group was significant, $F(2, 52) = 6.14$, $p = .004$, $\eta_p^2 = .191$ (see Figure 6.4).

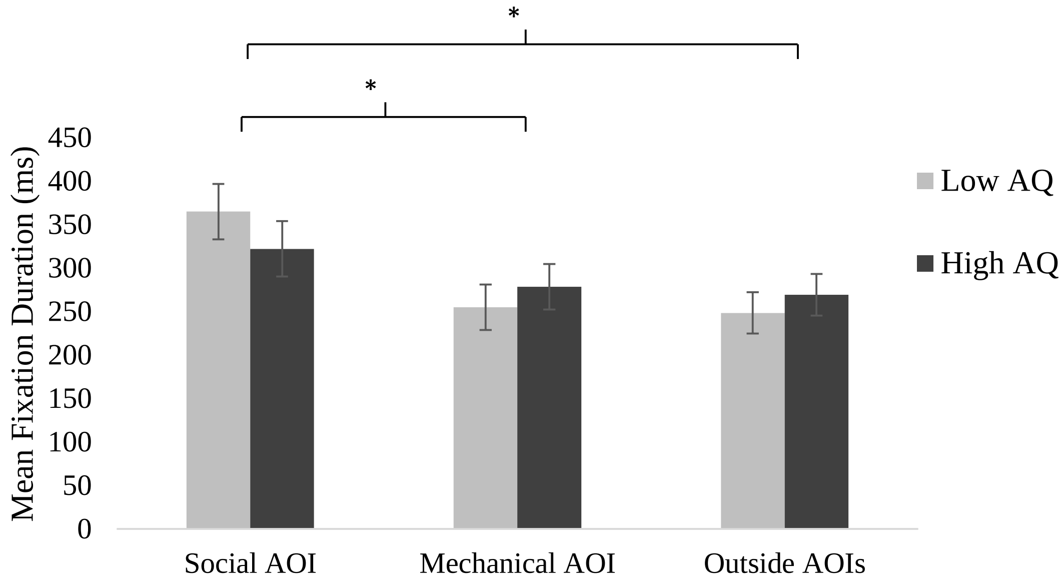

Figure 6.4. Mean fixation durations within Social and Mechanical AOIs, and outside either AOI for Low and High AQ groups. Error bars show standard error of the mean. * $p < .05$.

Independent samples t-tests showed a non-significant trend for participants in the Low AQ group to have longer fixations within Social AOIs than the high AQ group, $t(26) = 1.96$, $p = .061$, $d = 0.77$. There was no significant difference between groups in the length of fixations in Mechanical AOIs, $t(26) = -1.31$, $p = .202$, $d = -0.51$, or outside the AOIs, $t(25) = -1.26$, $p = .218$, $d = 0.49$. Paired samples t-tests within each group revealed that fixations were longer in social AOIs than mechanical AOIs for both the Low AQ group, $t(13) = 5.88$, $p < .001$, $d = 1.57$, and the High AQ group, $t(13) = 2.76$, $p = .016$, $d = 0.74$. Additionally, fixations were longer in the Social AOIs than outside either AOI for both the low AQ group, $t(13) = 6.65$, $p < .001$, $d = 1.78$, and the high AQ group, $t(13) = 3.68$, $p = .003$, $d = 0.98$. There was no significant difference between the length of fixations within Mechanical AOIs or outside either AOI for either the low AQ group, $t(13) = 0.67$, $p = .517$, $d = 0.18$, or the high AQ group, $t(13) = 0.70$, $p = .494$, $d = 0.19$. The results of the t-tests are unusual as the interaction between group and AOI was significant, but no between or within group comparisons reached significance when this interaction was explored. It appears that the interaction was driven by the between group difference in length of fixations in Social AOIs which approached significance ($p = .061$).

Discussion

This experiment investigated free viewing of scenes containing social and mechanical elements in relation to subclinical autism traits. Specifically, differences were looked for in the orienting of attention towards social and mechanical objects, disengaging attention from social and mechanical objects, and the overall proportion of time that was spent fixating on each type of object. Higher autism traits were associated with less time overall fixating in social AOIs than lower autism traits, and more time fixating outside of either Social or Mechanical AOIs on the background of the scenes. There was also a trend for those with higher autism traits to have shorter fixations on social elements in scenes than participants with lower levels of autism traits. No relationship was found between autism traits and the latency of first fixations on either social or mechanical elements of scenes. Autism traits were not found to relate to attention towards mechanical objects. Together, these results show that higher autism traits are associated with differences in social attention related to the disengaging and holding of attention, but not in the initial orienting of attention towards social information.

The relationship between higher AQ scores and reduced fixation time on social elements within scenes of everyday life is consistent with previous findings of decreased social attention related to autism traits in the general population (e.g. Swanson et al., 2013). Reduced attention to social information has been reported in the BAP, as Dalton, Nacewicz, Alexander, and Davidson (2007) found that siblings of children with ASD showed reduced gaze to the eye region of faces compared to controls. The present study expands on these previous findings and shows that adults with high autism traits in the general population are less likely than those with fewer autism traits to look at people within everyday scenes. The amount of time that participants spent fixating within different areas of scenes is indicative of top down control of selective attention, and thereby indicates interests and motivations. Participants with high levels of autism traits, therefore, appear to show less interest in social elements of natural scenes than individuals with fewer autism traits. This may be indicative of reduced social motivation as predicted by the Social Motivation Theory, and of a reduced interest in social information as described in the EMB theory of autism. Instead, individuals with high levels of autism traits were found to spend a larger amount of time fixating outside the social or mechanical areas of interest than individuals with low levels of autism traits. This finding may be relevant to WCC and EPF accounts of autism as it could be indicative of focusing attention more on minor details within the scenes such as those in the background areas rather than the people within the scenes which appeared more salient to the participants with low levels of autism traits. It would be worth comparing participants' fixation patterns to a saliency map of the scenes (Itti & Koch, 2000), as in Amso, Haas, Tenenbaum, Markant, and Sheinkopf (2014), to establish whether bottom up influences on attention predicted the allocation of visual attention to a greater degree in those with higher levels of autism traits than those with lower levels. The participants with high levels of autism traits spent the same amount of time fixating within social areas of scenes as they did the background of scenes suggesting that neither area was receiving attentional priority in the allocation of attention. However, it should be noted that the area outside either AOI covered a larger area of the screen than the social elements and so by allocating the same amount of time to fixating these two areas, participants with high levels of autism traits are proportionally attending more to social areas than the background, but not to the same degree as individuals with low levels of autism traits. The differences in amount of time spent fixating on social areas within scenes between those with high and low levels of autism traits suggests that differences in social attention, such as those found in people with ASD (e.g. Klin et al., 2002; Riby & Hancock, 2008) are part of a spectrum of social behaviour related to autism traits that is evident below a clinical threshold. The present study supports the notion that visual attention to social information is atypical, not just in those with a diagnosis of ASD, but also in individuals from the general population with high levels of autism traits.

Where people first fixate within a scene provides an indication of which element immediately captures attention and can be likened to selective orienting of attention. Previous research has found differences relating to first fixations in social and non-social scenes in ASD. When two scenes, one of which contained a person and one which did not, were presented together, Fletcher-Watson et al. (2009) found that individuals with ASD were less likely to initially fixate on the scene containing a person compared to controls. This suggests a reduction in the attentional priority of social information when viewing scenes in ASD. However, no differences were found between participants with high and low autism traits and the latency to make first fixations in social areas of scenes in the present study. This suggests that while individuals with higher levels of autism traits allocated less top down selective attention towards social information in scenes, as shown by this group spending more time fixating on the background of scenes and less time fixating on the social elements, there were no differences between those high and low in autism traits in relation to what initially captures attention when looking at a natural scene. All participants were found to first fixate the social elements of scenes faster than mechanical objects or the background. This shows that the people in scenes were rapidly capturing attention whereas other elements were not, regardless of levels of autism traits. This could mean that the difference found in ASD does not relate to autism traits in a subclinical population. The dot probe study in Chapter 4 found that males with high levels of AQ traits show a trend towards slowed orienting of attention towards faces. The primarily female sample in the current study prevented any meaningful exploration of differences in sex and autism traits in relation to the orienting of attention. This sample difference may be why no relationship was found between autism traits and orienting attention towards social information, as measured by the proportion of first fixations in each AOI, and a higher number of male participants, and participants scoring highly on the AQ is needed to fully explore this possibility.

A non-significant trend was found for higher levels of autism traits to be associated with shorter fixations on social elements of scenes than participants with lower levels. This indicates that social information within scenes does not hold attention to the same degree in individuals from the general population with high levels of autism traits relative to those with low levels. The measure of fixation duration was taken as an indication of disengagement from the point of fixation. Longer fixations indicate slower disengagement from the area that is being fixated.

Therefore, the trend for participants with higher AQ scores to be quicker to disengage from fixations in social areas suggests that these elements of scenes are not holding attention to the same extent as in participants with lower levels of autism traits. Disengaging attention is controlled by top down attentional processes (Theeuwes & Belopolsky, 2012) and as such is influenced by the salience of objects in the visual field to the observer. Shorter fixations on the social elements of scenes in people who scored higher on the AQ than people who scored lower suggests that people within scenes have a reduced salience in those with higher levels of autism traits compared to those with fewer autism traits. Previous research has found faster disengagement from faces in participants with ASD compared to typically developing controls (Chawarska et al., 2010; Kikuchi et al., 2011), and the present findings of a trend for faster disengagement from faces suggest that this difference is present in those with subclinical autism traits as well as those with a diagnosis of ASD, although perhaps to a lesser degree. This result in the present study was also a trend, and was just above the statistical threshold needed for full significance. Therefore, the results need to be taken with some caution. The study included mostly female participants with relatively low AQ scores, and so a more diverse sample may illuminate stronger differences.

The present study uncovered a relationship between autism traits and the general measure of overt top down allocation of attention to social information within a scene in terms of overall fixation time on social areas of scenes. This result is similar to findings of reduced looking time to faces in people with ASD relative to controls (Riby & Hancock, 2008). A trend was found towards slower disengaging from social information in relation to lower levels of autism traits. Disengaging attention is also influenced by top down control (Theeuwes & Belopolsky, 2012). However, there was no suggestion that the more automatic area of orienting attention to social information was related to autism traits to the same degree that differences have been found in those with ASD compared to typically developing controls (e.g. as in Fletcher-Watson et al., 2009). Therefore, whether social attention is atypical in relation to subclinical autism traits, as has been found in ASD, was dependent on the element of attention that was measured. This may be because autism traits do not relate as strongly to more subtle measures of visual attention at an automatic level as they do to a general diminished allocation of attention to social information as a result of lower social interest. This could be because the orienting of attention towards faces, which the latency to first fixation variable explores, has been found to be automatic rather than voluntary (Crouzet et al., 2010), whereas in free viewing across the entire scene presentation duration, the fixations to social objects are under volitional control. Studies have shown that during free viewing, gaze patterns are not simply driven by bottom up information when there are people present in the scene (Birmingham, Bischof, & Kingstone, 2009; Freeth, Foulsham, & Chapman, 2011). Therefore there may not be any differences in the rapid, automatic attentional capture of social information within scenes in people with high levels of subclinical autism traits, but differences in social attention do emerge when the attention of individuals is driven more by top down processes. Schultz (2005) suggests that deficits shown by people with ASD in face perception are a result of cortical processing differences in the amygdala and fusiform gyrus. It is thought that automatic, subcortical orienting towards faces via the amygdala may result in diminished cortical specialisation for faces in the FFA. It could be the case that people from the general population with high levels of autism traits are able to process faces in a typical way, unlike individuals with clinical levels of autism traits, and are therefore not showing a reduction in orienting to faces. Instead, individuals with high autism traits may have diminished social motivation as is found in individuals with ASD (Chevallier et al., 2012), but differ from those with a diagnosis of ASD in that they have developed the cortical specialisation which results in rapid orienting to and detection of faces (Crouzet et al., 2010).

Whilst relationships were found between autism traits and reduced visual attention to the social elements of scenes, no relationships were found between higher autism traits and attention towards mechanical items in everyday scenes. Therefore, whilst participants with high levels of autism traits were allocating less visual attention to social elements of scenes, this was not because they were allocating more to the mechanical elements. This is contrary to Sasson and Touchstone (2013), who found that participants with ASD spent less time fixating on a face when it was presented with an object of high CI than when it was paired with an item not related to CIs. This suggests that participants with high AQ scores were not looking at faces less because they were looking at mechanical objects more, rather it would appear that they were spending more time fixating outside the two AOIs. In relation to the EMB theory of autism, it would be predicted that those with higher levels of autism traits would preferentially attend to the mechanical elements of the scenes, representing systems, and less towards the social elements of scenes. Whilst the latter held true, the former was not supported in the present study. This could be due to the low proportion of males and the high proportion of females in the present study, as females have been shown to demonstrate higher levels of empathy and lower levels of systemising (Baron-Cohen, 2009; Carroll & Chiew, 2006). Therefore, the present sample may have had a particularly low interest in mechanical objects as a domain of CIs related to systemising. Furthermore, the participants in the present study were all psychology undergraduates. In the development of the AQ, students in biological sciences, which included psychology students, were found to score lower than students of other types of sciences (Baron-Cohen, Wheelwright, Skinner, et al., 2001). Additionally, psychology students have been found to have higher levels of empathy than other types of students (Rasoal, Danielsson, & Jungert, 2012) which means that the participants in the present study are likely to have had a greater empathic drive meaning that they looked more at social elements of scenes than other types of participants might have, and less at the mechanical elements (Baron-Cohen, 2002). Once again, a more diverse sample is required to further test whether high levels of autism traits are related to an increase in attention to objects of CI in ASD.

A further measure that would be useful in future eye tracking research exploring attention to social and non-social objects in the autism spectrum would be measurement of saccade paths (Irwin, Colcombe, Kramer, & Hahn, 2000). Analysis of saccade paths would reveal whether participants' gaze was drawn towards any areas of the scene rather than moving directly to the target of fixation and as such would reveal the salience of elements of the scene. This may help to elucidate bottom up influence on gaze behaviour such as colour which may distract gaze from its intended target. This may also reveal automatic capture of attention by faces or body parts as a participant may make a saccade that arcs towards an area of the scene that has automatically captured attention en route to the next fixation location.

As found in chapters 4 and 5, no relationship was evident between social anxiety and any of the measures of visual attention. This shows that levels of autism traits contribute to atypicalities in visual attention towards social information and this is not the result of increased social anxiety, which has been found to correlate to autism traits (White et al., 2011) and result in an attentional avoidance of faces (Chen et al., 2002).

In conclusion, autism traits were associated with diminished fixation time on social elements of natural scenes during free viewing and increased fixation time on the background of scenes. There were no differences in orienting to different areas of the scenes in those with high or low levels of autism traits, and a trend was found for those with higher levels of autism traits to have shorter fixations on social elements of scenes than participants with lower levels, and longer fixations on the background of scenes. This may be due to diminished social interest in relation to autism traits that is manifest in selective attention under top down control, but not in relation to the automatic capture of attention. There was no evidence to suggest autism traits are related to increased visual attention to mechanical objects.

Chapter 7

Orienting of Attention to Social and Mechanical Objects in Autism Spectrum Disorder

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Chapter Abstract: The present chapter utilises the same dot probe methodology as in Chapter 4 to investigate selective orienting of attention to social and mechanical objects in those with a diagnosis of ASD compared to typically developing controls. There was no group difference in the orienting of attention to faces and cars as all participants showed a greater attentional bias towards faces than cars. However, the control group showed an absolute attention bias to faces whereas the ASD group did not. This suggests that whilst faces capture attention to a greater extent than mechanical objects in ASD, they do not capture rapid orienting to the same degree in ASD as in typical development. Additionally the ASD group were found to have smaller attentional biases to either object category than the control group. It is suggested that the ASD participants were more influenced by the bottom up visual properties of the stimuli rather than their global meaning.

Faces are found to rapidly capture attention to a greater degree than other objects in typical development (Bindemann et al., 2007; Birmingham & Kingstone, 2009). It is thought that faces are prioritised in the orienting of attention via an early detection subcortical route and cortical specialisation for faces (Schultz, 2005). Some argue that inattention to faces and other social information contributes to the development of social difficulties in those with ASD (Dawson et al., 2004) as this can impact on interpreting and responding to social cues. However, research is mixed as to whether individuals with ASD do demonstrate atypical attention to social information.

The orienting of attention can be examined through the use of eye tracking. Measures of first fixation give an indication of what part of the visual field immediately captures attention. Fletcher-Watson et al. (2009) presented ASD and control participants with images where one half of the screen contained a scene with a person in it, and the other half showed a scene without a person. On a broad measure of looking time to each half of the scene, the ASD and control groups were found to look at the person present scene more than the person absent scene. However, analysis of first fixations showed that the ASD group had a lower proportion of first fixations within the person present half of the screen than the control group, and a lower proportion of first fixations on the person within the person present scene than the control group. This suggests that although the ASD group might show a similar general attentional preference for social information, this social information does not receive the same priority compared to typical controls because it is not immediately capturing the attention of the ASD group. Similarly, Riby and Hancock (2009a) found that participants with ASD took longer to first fixate on a face when it was embedded in a natural scene than typically developing controls and participants with Williams' syndrome. This finding is further supported by Freeth et al. (2010) who also found that participants with ASD took longer to first fixate on the face of people in scenes than control participants. These results suggest that the initial orienting of attention towards social information is reduced in ASD compared to typical controls. However, other studies have reported no difference in the orienting of attention to social information in ASD. Wilson, Brock, and Palermo (2010) found that both participants with ASD and typically developing controls had more first fixations on people within natural scenes than on other objects during a free viewing eye tracking task. Similarly, Fischer et al. (2013) explored social orienting in a gap overlap task using eye tracking. Both the ASD group and the control group were found to be faster to make a saccade to a peripheral social stimuli than non-social stimuli. This shows that both the ASD and control participants' attention was rapidly captured by social information to a greater degree than other objects. Therefore results are mixed with regards to whether faces receive the same rapid attentional priority in ASD that is seen in typical development.

The picture of whether ASD is associated with a reduction in social attention is not a simple one. Eye tracking studies may find a reduction in one measure of attention to faces, such as the time taken to first fixate a face, but also find equal proportions of overall fixation time to social elements of scenes (Fletcher-Watson et al., 2009; Kuhn et al., 2010). Therefore when looking at automatic, rapid orienting of attention, it is useful to employ methodology which specifically measures this element of visual attention in a controlled experimental setting. A handful of studies have begun to explore rapid attentional orienting in ASD using dot probe experiments. Dot probe experiments reflect attention towards objects which are particularly salient to the individual. As such, it would be expected that people will show an attentional bias towards faces over other types of objects because they are rewarding in terms of potential social interactions and as a source of information about the environment (Chevallier et al., 2012). Eye tracking studies measure overt visual attention whereas dot probe studies can tap into attention before a saccade is generated, and therefore measure early, automatic orienting (Bradley et al., 2000).

As with other methodologies, research using the dot probe task in ASD has produced mixed findings with regards to social attention. Moore et al. (2012) used images of faces, cars and houses presented at subliminal and supraliminal durations. It was found that participants with ASD did not exhibit a typical attention bias towards faces when images were presented at the supraliminal threshold duration (200ms). This suggests atypical social orienting in ASD. However, Shah et al. (2013) found evidence of typical social orienting in ASD. The participants with ASD were found to show the same pattern of orienting attention as the control group, with faster reaction times to locate the target when it was in the location of stimuli consisting of face-like configurations compared to non-face configurations. The authors suggest that social difficulties in ASD may be the result of diminished social attention driven by lower social motivation as opposed to innate, subcortical face detection differences. This suggests that the mechanism which results in rapid, automatic orienting of attention towards faces in typical development is intact in ASD, contrary to the findings of Moore et al. Therefore, the question remains open as to whether individuals with ASD selectively orient attention towards faces when paired with images of other objects, and the present study aims to contribute to this debate.

The EMB theory of autism (Baron-Cohen, 2002) suggests that people with ASD have a lower drive to empathise, or to show interest in the social world, and an increased drive to systemise. This would predict that people with ASD would not necessarily demonstrate an attentional preference towards social images, but might show an attentional preference towards images representing closed systems. Additionally, if people with ASD are not motivated to pay attention to social information because it is of less interest to them than typically developing individuals (Chevallier et al., 2012), they may be more motivated to pay attention to objects which are of more interest to them. Research has frequently identified vehicles as objects of particular interest to people with ASD (e.g. DeLoache et al., 2007; Golan et al., 2010; South et al., 2005), and Sasson and Touchstone (2013) found that objects of circumscribed interest to people with ASD can interfere with attention to social information. Items frequently identified as being of circumscribed interest in ASD include vehicles and mechanical objects (South et al., 2005; Turner-Brown et al., 2011). Therefore, the present study utilises images of cars as a representation of a mechanical category of circumscribed interests as cars also have configural similarity to faces (see Chapter 4 for further discussion on the selection of cars).

As in previous chapters, it is important to consider social anxiety when investigating social attention in ASD. Hollocks, Ozsivadjian, Matthews, Howlin, and Simonoff (2013) found that individuals with ASD and high levels of anxiety did not demonstrate an attention bias towards threatening stimuli which is typically observed in highly anxious people. This suggests that anxiety may affect visual attention differently in ASD relative to typical development. People with ASD have been found to have high levels of comorbid social anxiety (Simonoff et al., 2008; White, Oswald, Ollendick, & Scahill, 2009), and levels of social anxiety have been found to increase with age in ASD (Kuusikko et al., 2008). Social phobia in typical development has been associated with an attentional bias away from faces (Chen et al., 2002), and high social anxiety in a typically developing non clinical group was found to be related to an attentional bias towards faces over household objects in a dot probe task (Garner et al., 2006). Therefore it is important to consider social anxiety in any measure of attention towards faces in an ASD group as they are likely to experience higher levels of social anxiety relative to the typically developing population, which may impact on attention to faces.

The present study uses a dot probe task, as in Chapter 4, with presentation times of 200ms and 500ms to capture rapid automatic orienting of attention, and attention orienting that may occur later in participants with ASD as a result of slower face processing strategies (Deruelle et al., 2004) or slowed orienting of attention (Townsend, Courchesne, et al., 1996).

In chapter 4, it was found that males with high levels of autism traits showed a delay in orienting their attention to faces relative to males with low autism traits. This pattern was observed to a lesser degree in females as high autism trait females showed an absolute attention bias towards faces at 500ms only, but no differential pattern in terms of attention to faces and cars was found between females with high and low levels of autism traits. This is argued to be because of differing presentation of autism traits in males and females, and a buffer of superior social skills in females, as demonstrated by Bayliss et al. (2005). Research has often found that attentional differences that have been found in ASD are shown to a lesser extent in individuals with sub clinical autism traits or who have a first degree relative with ASD (Elsabbagh, Volein, Holmboe, et al., 2009; Rutherford, 2013). Therefore it would be expected that a stronger difference in face biases would be found when comparing a clinical ASD group with typically developing control participants. Note that sex was not included in the present analysis due to the higher proportion of males with a diagnosis of ASD (Ehlers & Gillberg, 1993).

The aim of the present experiment was to investigate attention orienting towards faces and mechanical objects in participants with ASD and control participants over both short and long display durations. It was hypothesised that participants would display greater attention biases towards faces than cars overall. Furthermore, it was expected that those with ASD would show a smaller attentional bias towards faces than control participants, and that this bias would differ over the two presentation durations. More specifically, ASD participants would show a reduction in orienting towards faces at 200ms, but increasing orientation at 500ms, similar to the pattern seen in males with high levels of autism traits in chapter 4. It was hypothesised that people with ASD would show a greater Attention Bias towards car stimuli compared to controls.

Method

Participants

Control participants (N = 23) were recruited through advertising at the University of Bath. ASD participants (N = 23) were recruited from personal contacts at the University of Bath, the Student Services department at Bath Spa University, advertising on websites for individuals with ASD, and contacting local supported living establishments for people with ASD.

The inclusion criteria for the ASD group were males or females aged 18 or over with a clinical diagnosis of an ASD with normal or corrected to normal vision, English as their first language and overall IQ scores on the WASI greater than 70. Exclusion criteria were if they were taking any medication that affected their cognitive abilities. For the control group, inclusion criteria were males or females aged 18 or over, with normal or corrected to normal vision and

English as a first language. Exclusion criteria were any psychiatric diagnoses or any medication affecting cognitive abilities.

Twenty three adults with a diagnosis of ASD and 23 typically developing controls took part. Two of the participants in the ASD group were diagnosed with high functioning autism, and twenty with Asperger's Syndrome. One participant with ASD was excluded as we were not able to obtain a full data set from them, and another participant was excluded as they did not maintain attention to the screen throughout the task and spent a lot of time looking at the keyboard. The inattention to the task by this participant was confirmed by their extremely long reaction times to trials (mean RT = 1263ms; ASD group mean RT = 626ms). One control participant was excluded as they had previously been assessed for ASD and scored 36 on the AQ, so their inclusion as a typically developing control participant was questionable.

The groups did not differ on age, sex or IQ. There were 7 females per group and 16 males before any participants were excluded (see Table 7.1 for sex characteristics of the groups as included in analyses). Mean ages and IQ scores are shown in Table 7.1 for those participants that were retained in analysis. There was no significant difference in mean age between groups, or across groups in verbal IQ, performance IQ, or on overall IQ scores (see Table 7.1).

Table 7.1

Demographic Information and mean questionnaire scores (SD)

	ASD (n = 20)	Control (n = 22)	Group comparison Statistics
Males: females	14:6	15:7	$\chi^2(1, N = 42) = 0.02, p = .899$
Mean Age (*SD*)	27.55 (8.50)	25.95 (5.74)	$t(40) = 0.72, p = .48$
Mean Verbal IQ (*SD*)	110.06 (8.15)	108.77 (11.17)	$t(40) = 0.41, p = .69$
Mean Performance IQ (*SD*)	112.72 (9.31)	115.50 (7.96)	$t(40) = -1.02, p = .32$
Mean overall IQ (*SD*)	112.67 (7.55)	113.45 (7.78)	$t(40) = -0.32, p = .75$
Mean AQ score (*SD*)*	32.05 (8.55)	17.45 (5.95)	$t(40) = 6.47, p < .001$
Mean LSAS score (*SD*)*	62.75 (31.07)	34.23 (21.74)	$t(40) = 3.47, p = .001$

Note: AQ = Autism Spectrum Quotient (maximum score 50); LSAS = Leibowitz Social Anxiety Scale (maximum score 144)

Of the final ASD group, 18 identified their ethnicity as white European, 1 Indian and European, and 1 Chinese. Of the control group, 17 identified as white European, 3 Chinese, 1 African and 1 Indian descent.

Participants completed the AQ to measure the degree of autism symptoms. The ASD group had significantly higher AQ scores than the control group (see table 7.1). The group mean of 32.05 is at the cut off suggested by Baron-Cohen, Wheelwright, Skinner, et al. (2001) to distinguish individuals with a diagnosis of ASD. It is also well above the cut-off of 26 suggested by Woodbury-Smith et al. (2005). For further discussion of participant characteristics, see Chapter 3.

Materials and Procedure

Participants completed a dot probe task with 256 trials of image pairs consisting of a face or car paired with a house. Image pairs were presented for 200ms or 500ms. Participants were instructed to identify the type of dot target shown (: or ..) in place of one of the images as quickly and as accurately as possible by pressing a button on the keyboard (the up arrow or the right arrow). See Chapter 4 for more information about the design.

Participants also completed the AQ (Baron-Cohen, Wheelwright, Skinner, et al., 2001) and LSAS (Baker et al., 2002), which are described in detail in Chapter 4. Participants were also administered the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). This is a shorter version of the full Wechsler Adult Scale of Intelligence and comprises of four tests, two of which measure performance IQ (block design and matrix reasoning) and two which measure verbal IQ (vocabulary and similarities). The WASI took approximately 30 minutes to administer. Experiments and questionnaires were completed in a randomised order for each participant. Due to the length of the testing session, participants were advised they could take breaks in between tasks if they wanted to.

Participants with ASD received £20 for their time and reimbursements for travel to the University of Bath and for refreshments as necessary. Control participants received £20 for their time.

Results

Data Preparation

Trials with incorrect responses, with reaction times below 200ms, and reaction times 2.5 standard deviations above the participant's individual mean reaction time were removed from the data, as in Chapter 4. One participant from the ASD group's data was not used in analyses as 14.06% of their trials were removed due to errors. This was more than 2.5 standard deviations from the mean percentage of data discarded across participants indicating inattention to the task. This meant the final size of the ASD sample included in the analysis was 20, as shown in Table 7.1. The mean proportion of errors for the remaining participants was 2.80% and 2% for outliers. There was no difference in the proportion of trials discarded due to errors in the ASD group (3.84%) and control group (2.54%), $t(42) = 1.58$, $p = .12$; nor in the proportion of trials discarded due to outlying reaction times (ASD mean 1.90%, control mean 2.02%), $t(42) = -0.55$, $p = .59$.

There was no difference in overall mean reaction time between the ASD (598ms) and control (595ms) groups, $t(40) = 0.08$, $p = .93$.

Attention Bias score

As in Chapter 4, an Attention Bias Score was computed as an index of whether participants were faster to detect a target when presented in the location of a stimulus category of interest or at the opposite location. Raw reaction time data can be found in Appendix V. Additionally this removes the potential confound of group differences in reaction times. Bias scores were calculated by subtracting face/car congruent reaction times from face/car incongruent reaction times at each presentation duration. This created four Attention Bias Scores, one for each stimulus of interest at 200ms and 500ms (see Table 7.2 for means). A higher positive score indicates a greater attentional bias to that stimulus. A negative score indicates a bias away from that stimulus (or towards the neutral pairing).

Table 7.2

Mean Bias scores for ASD and control groups (ms)

	ASD (n = 20)	Control (n = 22)
200 Face Bias	5.54	23.51
500 Face Bias	13.22	29.35
200 Car Bias	-14.00	10.36
500 Car Bias	-14.86	1.47

The four Bias scores were tested for normality. Face Bias scores at 200ms for the ASD group were somewhat negatively skewed according to the histogram which appeared to be influenced by an extreme case in the left hand tail of the distribution. This was confirmed by the Shapiro Wilk test for normality which revealed that Face Bias Scores at 200ms for the ASD group significantly differed from a normal distribution, $W(20) = .89$, $p = .023$. Additionally, the Car Bias Scores were found to violate the assumption of normality according to the Shapiro Wilk test, $W(20) = .89$, $p = .023$. Neither bias score at 500ms differed from normality for the ASD group, and none of the four bias scores differed from normality for the Control group, all p's > .1. It was found that one ASD participant had a Face Bias score at 200ms with a Z score greater than +/- 3.29. The Z score for the same participant almost reached outlier criteria for their Car Bias score at 200ms ($Z = -3.27$). Removing this participant's data from the ASD group meant that all bias scores were normally distributed (all p's on Shapiro Wilk test > .2). However, given the small sample size, the known heterogeneity of individuals with ASD, and the robust nature of ANOVAs, this participant's data was retained in analyses. To explore whether this individuals outlying bias scores were influencing the analysis, it was re-run with their data omitted. The results were not found to change further validating their inclusion in the main analysis (see Appendix V).

Social Anxiety

As in previous chapters, given the links between social anxiety, ASD and attention to faces, correlations of the Face Bias scores with LSAS scores were performed for the ASD and Control groups. None of the Pearson's correlations approached significance between LSAS scores and Face Bias scores at 200ms or 500ms for participants with ASD or Control Participants, all *r*s < .14, all *p*s > .5.

Analysis

A Group (ASD v control) x Bias (face v car) x Time (200ms v 500ms) ANOVA was performed with Attention Bias Score as the dependent variable, and revealed a main effect of Bias, $F(1, 40) = 29.43$, $p < .001$, $\eta_p^2 = .424$, with Face Bias scores ($M = 17.90$) being greater than Car Bias scores ($M = -4.26$) for all participants (see Figure 7.1). There was also a main effect of Group, $F(1, 40) = 10.13$, $p = .003$, $\eta_p^2 = .202$, with Bias scores being greater for controls ($M = 16.17$) than for ASD participants ($M = -2.53$). Importantly, the Group x Bias interaction was not significant, $F(1, 40) = 0.16$, $p = .689$, $\eta_p^2 = .004$, nor was the Group x Bias x Time interaction, $F(1, 40) = 0.16$, $p = .690$, $\eta_p^2 = .004$. No other main effects or interactions approached significance (all *F*'s < 2.28, all *p*'s > .14).

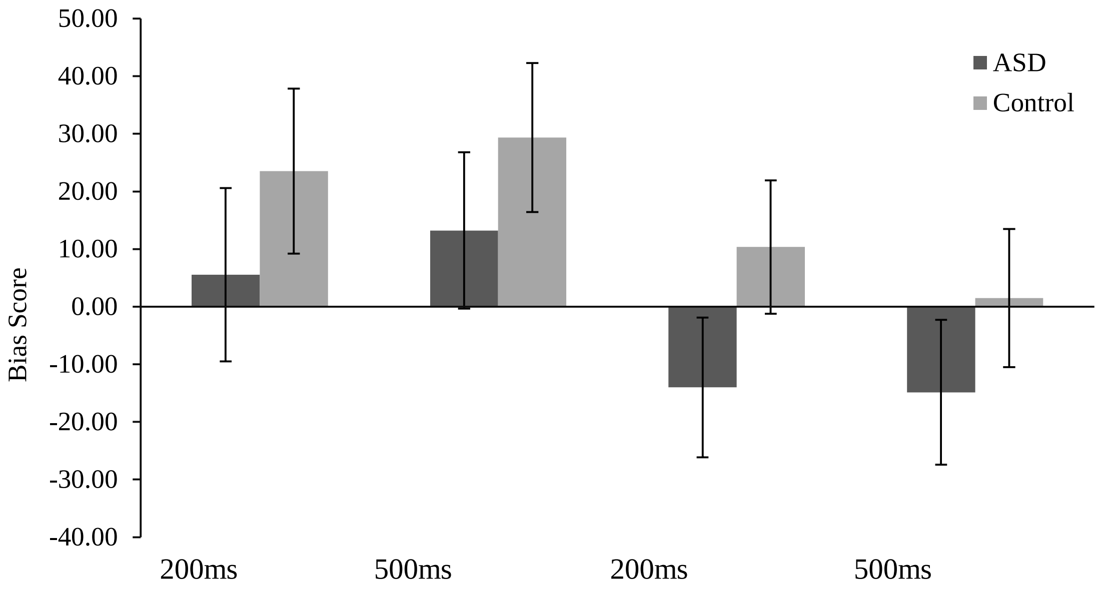


Figure 7.1. Bias Scores for Face and Car Stimuli at 200ms and 500ms for ASD and Control groups. Error bars show 95% confidence intervals of the Mean.

The four Bias Scores (for faces and cars at 200ms and 500ms) were subjected to one sample t tests for the ASD and Control Groups to establish whether they significantly differ from zero and represent an absolute attentional bias (as in e.g. Moore et al., 2012). A Bias Score of zero would mean no significant attentional bias towards one type of stimuli over the other; i.e. Face incongruent reaction time = face congruent reaction time. As there were eight comparisons, a Bonferonni correction was applied to give an alpha level of .006.

For the Control Group, the mean Face Bias scores at 200ms, $t(21) = 3.60$, $p = .002$, $d = 0.79$, and 500ms, $t(21) = 4.79$, $p < .001$, $d = 1.05$, were significantly different from zero (see Figure 7.1). The two Car Bias scores did not differ significantly from zero, $t(21) = 1.79$, $p = .088$, $d = 0.39$, for Car Bias scores at 200ms, and $t(21) = 0.26$, $p = .798$, $d = 0.06$, for Car Bias scores at 500ms. For the ASD Group, none of the attention bias scores significantly differed from zero (Face Bias score at 200ms: $t(19) = 0.69$, $p = .499$, $d = 0.16$; Face Bias score at 500ms: $t(19) = 1.89$, $p = .075$, $d = 0.43$; Car Bias scores at 200ms: $t(19) = -2.36$, $p = .029$, $d = 0.54$; Car Bias scores at 500ms, $t(19) = -2.28$, $p = .034$, $d = 0.52$)

Discussion

The present experiment investigated the orienting of attention to social and mechanical stimuli in participants with ASD compared to control participants. It was found that faces captured attention more than cars across all participants. However, the ASD group did not show an absolute attentional bias towards faces at either presentation duration whereas the control participants did at both times. Additionally the ASD group were found to exhibit lower attention bias scores towards all types of stimuli than the control group. These results suggest that participants with ASD were less influenced by the content of the social and mechanical images than the control participants.

Across all participants there was a larger attention bias towards faces than cars which shows that faces captured attention to a greater extent than cars. This finding is consistent with the dot probe task in Chapter 4, where faces were found to elicit faster probe detection latencies than cars across participants with high and low levels of autism traits. This is in line with previous research that has shown that people preferentially orient their attention towards faces (Frank et al., 2009; Tomalski et al., 2009). The lack of group difference in the pattern of attentional biases towards faces and cars is contrary to the hypothesis that the ASD group would show a reduced attention orienting bias to faces than controls and a greater attention bias towards cars. This at first appears to support the findings of Fischer et al. (2013) who found in tact social orienting in 9 year old children with ASD in a gap overlap task, and to that of Shah et al. (2013) who also found that adults (with a mean age of 40) with ASD show typical orienting to face like stimuli in an experimental procedure similar to the dot probe.

However, the control participants showed an absolute bias towards faces, with mean face bias scores significantly differing from zero at both presentation durations. The dot probe task in Chapter 4 found that low AQ males demonstrated rapid automatic orienting to faces which was not evident at 500ms presentation times. The high AQ males did not show this rapid automatic orienting to faces at 200ms, rather it was evident at 500ms when there was sufficient time for attention to be shifted using more top down control. In the present study, the ASD group did not show an absolute face bias when images were presented for either 200ms or 500ms. Therefore faces were not eliciting rapid, automatic orienting or slower, top down orienting of attention to a greater extent than other objects in the visual field (the houses) for the ASD group. This suggests that both the subcortical route for rapid face detection (Johnson, 2005) and top down processes relating to interest in faces are impaired in the ASD group relative to the control group. This interpretation supports the Social Motivation Theory of autism (Chevallier et al., 2012) as it suggests that people with ASD are not driven to use top down strategies to orient attention towards people.

The ASD group had lower overall mean bias scores across both face and car stimuli, and both presentation durations. This means that the ASD group were not as drawn to any stimuli as the control participants. One possible explanation for this is that the ASD group were influenced by visual properties of the stimuli rather than their meaning. The house stimuli were rated as more complex than the car stimuli, most likely because the house images contain more edges and therefore more areas of contrast than the cars. This interpretation implies that the ASD group are not processing the content and meaning of the images to the same extent as control participants. The WCC account of autism (Happé & Frith, 2006) suggests that people with ASD tend to process objects in their visual field through local, detailed elements of images rather than interpreting their global meaning. Therefore the ASD group could have been more drawn to the details of the pictures than their overall content and therefore no category of stimuli was more semantically salient than any other. This could account for why the ASD group were drawn to the houses which were more complex than cars, resulting in the negative attention bias score for car stimuli. Navon tasks show that individuals with ASD demonstrate a local processing bias and greater interference from local rather than global features (Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000; Wang, Mottron, Peng, Berthiaume, & Dawson, 2007). This may be the result of bottom up information having a greater influence on the allocation of visual attention than top down information in ASD. Amso et al. (2014) used eye tracking with free viewing of scenes containing people where the person in the scene was either the most salient object in the scene or secondary to another object within the scene to explore the impact of bottom up influences on social attention in ASD. By comparing viewing patterns to a saliency map of the image, it was found that participants with ASD were more influenced by bottom up processes in their distribution of visual attention, regardless of whether a person was salient in the scene or not. This suggests that the orienting of attention in ASD is driven more by features of the visual field rather than top down influences. Similarly Chevallier, Huguet, Happé, George, and Conty (2013) used a Stroop task with social and non-social stimuli and found that social stimuli were less distracting for ASD participants than the non-social stimuli, whilst the opposite pattern was found in controls. This supports the current findings that face stimuli may not capture attention in participants with ASD and affect their performance on the dot probe task, but non-social house stimuli appeared to be capturing attention. Therefore it is suggested that the lower overall bias scores to the two stimulus categories of interest in the present experiment is likely to be because of a reduction in the semantic interpretation of the images in the ASD group relative to the control group and an increase in the influence of the bottom up properties of the stimuli.

Alternatively, this could be interpreted as an attentional bias towards houses in the ASD group as a result of interest or drive towards houses as a category of objects. It would be worthwhile to test this by presenting the face stimuli with the car stimuli as well as with the house stimuli, as in Moore et al. (2012), to establish whether each object category (cars or houses) differentially affected orienting towards faces. However, there is no evidence to suggest that houses are processed any differently in ASD compared to typical development (Bird et al., 2006; Humphreys, Hasson, Avidan, Minshew, & Behrmann, 2008; Kleinhans et al., 2008), and therefore it is unlikely that there is an innate attentional preference for houses in ASD. The preference that emerged when houses were presented with cars is more likely to be due to low level features of the house stimuli that captured attention to a greater extent in the ASD group than the control group. Additionally, this may also have led to a reduction in the face bias that was seen in the ASD group, causing it to be less strong as it otherwise might have been. The competition between an automatic orienting response to faces and the high visual saliency of the house images they were paired with could have caused a reduction in the face bias scores in the ASD group. However, the stimulus ratings did not suggest that there were any differences in the visual properties of the house and face images as they were rated equally in terms of complexity. Therefore it cannot be concluded that the reduction in face bias scores was a result of high visual saliency of the house image pairing.

The EMB theory of autism (Baron-Cohen, 2002) coupled with research suggesting that people with ASD may pay greater attention to objects of circumscribed interest than typically developing individuals (Sasson & Touchstone, 2013), would predict an attentional preference to objects related to systemising in people with ASD such as the car stimuli presented in the present study. However this was not found to be the case. Images of cars were chosen to represent a mechanical class of objects, and the negative bias scores for car images in the ASD group suggests that these participants were orienting their attention away from the cars (or towards the house images they were paired with). As discussed in Chapters 4 and 5, it could be the case that the car images were not necessarily relevant to areas of circumscribed interest to the participants in the present study. As mentioned previously, future research may benefit from establishing individual areas of circumscribed interest and create relevant stimuli to compare attention to faces with.

Contrary to predictions and the findings of Chapter 4, where high levels of autism traits in males appeared to be related to a delay in social orienting, there were no differences across presentation durations for either group. The same pattern of attention bias scores was found whether images were presented for 200ms or 500ms, suggesting faces capture attention to a greater extent than cars, whether this is rapid and automatic (200ms) or over longer durations where more top down control of attention could occur (500ms). However this was to a lower extent in the ASD group compared to the control group as they did not show an absolute attentional bias for faces at either time. It was expected that the ASD group may show a larger face bias score at 500ms than at 200ms due to either alternative methods of processing faces (Deruelle et al., 2004) or a general slowing of orienting attention (Townsend, Courchesne, et al., 1996). There were no differences in reaction times to identify targets between the ASD and control groups suggesting there were no differences in the speed of orienting attention. This therefore suggests that selective orienting in ASD is less biased towards faces than the control group both at the point of rapid orienting, and when the allocation of attention is under top down control. This may be because attention in ASD is more reliant on bottom up influences than top down (Amso et al., 2014; Pellicano & Burr, 2012), or because the participants with ASD are not influenced by the global meaning of images, as suggested by the WCC theory (Happé & Frith, 2006).

As was noted in Chapter 4, it would be interesting to consider the impact of inter-trial priming across participant groups and stimulus categories. The results from the present study, where participants with ASD were found to display less of an attention bias towards any type of stimulus, would perhaps indicate that participants with ASD would be less susceptible to inter-trial priming as they may have been processing the content and meaning of stimuli to a lesser degree than the Control Group. This may suggest less top down influence on the allocation of attention in participants with ASD, as noted above. Therefore the participants with ASD may be more successful in inhibiting biases towards certain categories of stimuli, although perceptual similarity may still have an impact in facilitating responses where targets occur in the location of the same type of stimulus as in the previous trial. Therefore it would be worth considering under what conditions inter-trial priming occurs in participants with ASD and typically developing individuals.

Also as noted in Chapter 4, IoR may have had an impact on results when stimuli were presented for 500ms as this is longer than the known stimulus presentation threshold for IoR of around 300ms (Klein, 2000)l. However, the pattern of results for stimulus types across groups does not differ across stimulus presentation times and it is therefore unlikely that IoR was impacting results at the longer presentation time of 500ms.

As in Chapters 4-6 which investigated visual attention in relation to autism traits in the general population, no relationship was found between social anxiety and the measures of attention bias. This suggests that higher levels of social anxiety found in this study and others (e.g. White et al., 2012) are not the underlying cause of differences in the orienting of attention to faces in ASD relative to typical development.

In conclusion, the results of the present study showed that across both ASD and control participants, faces captured attention more than cars. However, while those with ASD showed greater attention orienting to faces compared to cars, this effect was reduced compared to controls. Furthermore, those with ASD also showed reduced attention biases for cars compared to control participants, showing that generally people with ASD had reduced attention orienting to either social or mechanical items. Therefore, individuals with ASD appear to be less influenced by the semantic or global content of images and may orient attention based more on local, bottom up influences. There was no evidence to suggest that individuals with ASD orient preferentially towards mechanical objects. Taken together, this suggests that faces do capture attention in adults with ASD to a greater extent than cars, but not as strongly as in typically developing individuals.

Chapter 8

Attentional Disengagement from Social and Mechanical objects in ASD

Chapter Abstract: The present chapter explores the disengagement of attention from faces and cars in adults with ASD and typically developed adults using a peripheral cueing experiment. It was found that the ASD group were slower to disengage attention from faces than cars, but that the control group showed no difference in the time to disengage attention from faces compared to cars. This surprising result was explored with post hoc analyses including disengagement from houses, and both participants with ASD and control participants were found to be slower to disengage attention from faces than non-social stimuli. This suggests that in a controlled experiment where attention is automatically captured by faces, individuals with ASD demonstrate a typical delay in disengaging attention from faces.

People with ASD are thought to demonstrate a diminished attentional preference for people and faces, which is normally seen in typical development (e.g. Klin et al., 2002). This diminished social attention is frequently investigating in terms of 'social orienting', which involves giving social information priority in the initial allocation of attention (Bindemann et al., 2007). As well as investigating which objects draw attention in ASD, it is also important to explore whether particular objects might hold attention in ASD. If an object in the visual field holds attention, it is thought that this indicates that that object is particularly salient to the observer, and demonstrates a greater level of engagement with the stimulus (Derryberry & Reed, 2002; Fox et al., 2002). This can be explored by comparing the disengagement of attention from different types of object.

If a person is slow to disengage their attention from a point of fixation, it is thought that this object of fixation is of high salience to that person. For example, there is evidence to show that people with anxiety disorders are slower to disengage from threatening information than people without anxiety disorders (Fox et al., 2002; Mogg et al., 2008), and difficulty disengaging attention from drug relevant information is predictive of relapse in addiction (Marissen et al., 2006). In this way, attentional biases are thought to contribute to the perpetuation of such disorders. This illustrates how the allocation of attention can be driven by goals, beliefs and expectations in the observer (Yantis, 1996).

In typical development, research has focused on people's tendency to show an orienting preference towards faces versus other objects (Johnson, Dziurawiec, et al., 1991). In addition to this orienting preference, faces are found to hold attention and people are slower to look away from faces compared to other objects, with 4 to 8 month old infants looking for longer at faces compared to toys in a preferential looking task (DeNicola et al., 2013). Faces are also found to hold attention into adulthood, with Ro et al. (2007) finding that faces and body parts hold attention more than other objects. Additionally, Bindemann et al. (2005) found that faces held attention to a greater extent than other stimuli and interfered with responses to targets on a Go/No go task. Taken together these studies show that in typical development, faces hold attention and that it is therefore difficult to disengage from them relative to other types of stimuli.

The Social Motivation theory of autism would suggest that faces may not be as rewarding to people with ASD as they are to typically developing individuals (Chevallier et al., 2012). Therefore faces may not be as salient and could be associated with faster disengaging than in typical development. This has been found to be the case in gap overlap tasks. Using such a task, Chawarska et al. (2010) found that when the central stimulus was a face, the children in the control group were slower to disengage to the peripheral stimulus than the ASD group, suggesting faces resulted in difficulty disengaging attention for the control group but not the ASD group. In older children, with a mean age of 12.8, Kikuchi et al. (2011) also found evidence of difficulty to disengage from faces in the control group but not the ASD group in a gap overlap task. In their review of disengagement of attention in ASD, Sacrey et al. (2014) conclude that disengaging attention from faces is atypical in ASD, with people with ASD being quicker to disengage attention from a face compared to typically developing control participants. In contrast, Fischer et al. (2013) found no differences in disengagement from faces in a gap overlap task between children with a mean age of 9 years with ASD and typically developing controls. Therefore there are inconsistencies in the literature as to whether faces do not hold attention in ASD, and little research has examined this in adults.

Whilst attention may not be held by faces in ASD, objects which are of more interest to people with ASD may hold attention. Research has found that certain object categories, such as vehicles and machines, tend to be of higher interest to people with ASD (Baron-Cohen & Wheelwright, 1999; South et al., 2005; Turner-Brown et al., 2011) and these objects of CI can interfere with social functioning (Klin et al., 2007). Although autistic symptomology has been found to improve with age, Fecteau, Mottron, Berthiaume, and Burack (2003) found that the domain of restricted interests and repetitive behaviours was the area with least improvement in adolescents and adults with ASD. This suggests that atypical attention to objects of CI may persist into adulthood. If disengagement of attention is slowed when objects in the visual field are more salient to an individual because of their relative importance to an individual and relation to clinical symptoms (as in anxiety and addiction research), it is possible that objects which are of a greater interest to people with ASD may result in a slowed disengagement. Atypical attention to objects has been documented in ASD (Maestro et al., 2005; Swettenham et al., 1998), and it is thought that this disproportionate allocation of attention to non-social objects compared to social objects may contribute to both the restricted interests and repetitive behaviours in ASD as well as the social deficits (Sasson & Touchstone, 2013). Difficulty disengaging attention from objects of interest may prevent the individual from attending to more relevant information in the environment such as social cues, and inhibit them from attending to new stimuli resulting in the tendency to have restricted interests and repetitive behaviours (Maestro et al., 2005; Sasson & Touchstone, 2013).

To explore attentional differences in viewing social and non-social objects, Sasson et al. (2008) presented children with ASD with image arrays containing social images and images of either high (e.g. trains and electronic devices) or low (e.g. clothes and food) interest to people with ASD based on topics of CI identified by South et al. (2005). It was found that the children with autism fixated on fewer social images when they were presented with objects of CI, than when they were presented with objects which were not of CI. This suggests that there may be general attentional differences relating to objects of CI. A further study from the same research group compared visual attention to social and non-social object pairs in younger children with ASD (Sasson & Touchstone, 2013). Again, the non-social objects were either of high autism interest or low autism interest. It was found that the children with ASD showed a reduction in fixation durations on the face images when they were presented with an object of high autism interest. This suggests that objects which may be of more interest to individuals with ASD can interfere with social attention, however this has yet to be explored in adults.

Peripheral cueing tasks have commonly been used to investigate the disengagement of attention to different types of objects as the paradigm ensures that attention is engaged at the cued location because it elicits automatic exogenous orienting (Jonides, 1981). Typically, gap overlap tasks have been used to explore disengagement from different objects in ASD, with eye tracking to measure the latency to make a saccade towards a peripheral stimulus when a central stimulus remains on screen (e.g. Chawarska et al., 2010; Fischer et al., 2013). This experimental method therefore explores overt visual attention. The present peripheral cueing task explores covert attention thereby eliminating individual differences in the time taken to make saccades. Peripheral cueing tasks have been used to investigate disengaging attention generally in ASD (e.g. Townsend, Harris, et al., 1996) but have not been used as in the anxiety literature (e.g. Fox et al., 2002) to explore specific disengagement differences in ASD to different types of stimuli. This enables a test of whether slowed disengagement from faces seen in typical development is present in ASD, and whether there may be atypical attention biases to favour objects of CI in people with ASD. This is the first study to directly compare disengagement of attention from faces compared to cars, with the latter included as an object of CI in ASD, using a peripheral cueing task. As research has shown that people with ASD may need longer presentation durations to benefit from a peripheral cue (Townsend, Harris, et al., 1996), stimulus presentation times of 100ms and 800ms were used in the present research. Images of cars were used as the objects of CI in ASD owing to their configural similarity to faces, and the frequent identification of vehicles as objects of CI in ASD (e.g. South et al., 2005; Turner-Brown et al., 2011).

ASDs are associated with higher levels of social anxiety than the general population (White et al., 2009), and social anxiety has been found to relate to attention to faces in clinical and sub clinical populations (Chen et al., 2002; Garner et al., 2006). Specifically in relation to the disengagement of attention, social anxiety is linked to difficulty disengaging from negatively valenced emotional faces (Buckner, Maner, & Schmidt, 2010). Although emotional faces were not used in the present study (face stimuli consisted of neutral faces), it is possible that faces relative to non-social stimuli may represent a threatening social cue and elicit different disengagement of attention relative to social anxiety. It is also thought that social anxiety may influence visual attention to faces differently in ASD relative to typical development (Hollocks et al., 2013). Therefore social anxiety was measured in the present study to check whether it may be impacting on differences in the disengagement of attention from faces in the ASD and control groups, and ensure any differences found are the result of ASD rather than social anxiety.

Chapter 5 found that there was no difference in the pattern of disengaging attention from faces and cars relative to autism traits. Chapter 7 found that participants with ASD did not show an absolute attention orienting bias towards faces that was seen in control participants in a dot probe task suggesting a reduced attentional capture of faces in ASD. The present study builds on these findings by exploring the disengagement element of attention to faces and cars in people with a diagnosis of ASD.

The present study aimed to investigate the disengagement of attention to faces and cars in participants with ASD compared to controls. Due to a reported lack of social interest and diminished social attention in ASD, it was hypothesised the ASD group would show faster disengagement from faces than the control group, showing that faces do not hold the attention of the ASD group as much as the control group. Based on research showing differences in the disengagement of attention from objects of CI in ASD, it was predicted that the ASD group would show longer reaction times when a target was presented at the opposite location to a car image than the control group. Furthermore, it was hypothesised that differences in disengagement from face and car stimuli in participants with ASD would be most evident at presentation durations of 800ms as research has shown that participants with ASD are more influenced by cue location at 800ms than 100ms, whereas differences in disengagement in the control group would be most evident at 100ms compared to 800ms.

Method

Participants

The same control and ASD participants who completed the dot probe task in Chapter 7 also completed the peripheral cueing task. The present sample comprised of 20 adults with a diagnosis of an ASD, and 22 age, sex and IQ matched control participants (see Table 8.1). The same participants that were excluded after initial recruitment in Chapter 7 were also excluded here for the same reasons (the participant with a high number of erroneous and outlying reaction time trials in the dot probe task also had a high number in the present task, see 'data preparation' below).

Table 8.1
Demographic Information and mean questionnaire scores (ms) for Participants included in analyses

	ASD (n = 20)	Control (n = 22)	Group comparison Statistics
Males: females	14:6	15:7	$\chi^2(1, N = 42) = 0.02, p = .899$
Mean Age (*SD*)	27.55 (8.50)	25.95 (5.74)	$t(40) = 0.72, p = .48$
Mean Verbal IQ (*SD*)	110.06 (8.15)	108.77 (11.17)	$t(40) = 0.41, p = .69$
Mean Performance IQ (*SD*)	112.72 (9.31)	115.50 (7.96)	$t(40) = -1.02, p = .32$
Mean overall IQ (*SD*)	112.67 (7.55)	113.45 (7.78)	$t(40) = -0.32, p = .75$
Mean AQ score (*SD*)	32.05 (8.55)	17.45 (5.95)	$t(40) = 6.47, p < .001$
Mean LSAS score (*SD*)	62.75 (31.07)	34.23 (21.74)	$t(40) = 3.47, p = .001$

Note: AQ = Autism Spectrum Quotient (maximum score 50); LSAS = Leibowitz Social Anxiety Scale (maximum score 144)

Materials and Procedure

A peripheral cueing task was completed which was the same as in Chapter 5 (see Chapter 5 for further description of the task). It consisted of 360 trials where a face, car or house was presented for either 100ms (50% of trials) or 800ms on one side of the screen. Following this, a target appeared at either the cued or uncued location. The target was shown at the cued location on two thirds of trials, and was invalidly cued for the remaining one third. The participants' task was to identify the type of target that was shown (: or ..) by pressing a button on the keyboard.

Participants also completed the AQ and LSAS as described in Chapter 4 to measure autism traits and social anxiety respectively, and the WASI to measure IQ. Participants were reimbursed £20 for their time.

Results

Data preparation

Trials where the participant incorrectly identified the probe type were discarded. Reaction times faster than 200ms were removed as anticipatory, and reaction times over 2.5 standard deviations from the participant's mean reaction time were also removed. The mean percentage of erroneous trials across all participants was 3.05%, and the mean proportion of trials removed in the entire experiment due to outliers was 2.28%. One participant's data from the ASD group was excluded from analyses as the proportion of their data that was discarded due to errors and outliers (20%) was higher than 2.5 standard deviations above the mean percent of data discarded for each participant indicating inattention or difficulty with the task. This left 20 ASD participants and 22 control participants. There was no difference between the ASD group and Controls in the number of errors made in the task (3.91% erroneous trials vs 2.18%), $t(42) = 1.73$, $p = .091$. There was also no significant group difference in the proportion of trials discarded due to outliers, $t(42) = -0.06$, $p = .95$.

Mean reaction time scores were calculated for each cue type at each presentation duration for both valid and invalid trials (see Appendix VI). Since the costs of an invalid cue relative to the benefits of a valid cue were of interest, reaction times to identify validly cued targets were subtracted from those to invalidly cued targets to produce a Validity Score to give a measure of the disengagement of attention (Townsend, Courchesne, et al., 1996). In this way, individual differences of general slower reaction times are eliminated, as is the time taken to initially orient to the cue. The Validity Score represents the time taken to disengage from the cue and move to the target at the opposite location. This measure can be described as containing both the benefits of a valid cue, and the costs of an invalid cue (Jonides, 1981). A higher positive number indicates a greater validity effect, with reaction times being faster to valid cues than invalid cues. A negative number indicates that reaction times were faster when the target was invalidly cued. These validity scores were computed for each cue type at each presentation duration (see table 8.2)

Table 8.2

Mean Validity Scores (SD) in ms to identify target for ASD and Control Groups

Presentation Duration	Cue Type	ASC (*n* = 20)	Control (*n* = 22)
100ms	Face	45.88 (48.40)	33.54 (42.13)
	Car	17.57 (32.52)	35.06 (35.47)
800ms	Face	22.62 (56.22)	23.46 (26.69)
	Car	5.79 (43.73)	12.85 (38.52)

The four Validity Scores were tested for normality of distribution. Histograms and QQ plots appeared to show that all of them followed a normal distribution, and this was confirmed by the Shapiro Wilk test which was non-significant for all four Validity Scores for both the ASD and control groups, all W's > .94, all p's > .20. No participants were found to have outlying mean Validity Scores across any of the variables. For all participants, Z scores for mean Validity Scores for faces and cars at 100ms and 800ms were < +/-3.29.

Social Anxiety

As in previous chapters, Pearson's correlations were initially conducted with LSAS scores against reaction times to Face variables to explore whether social anxiety was related to disengagement from face cues. Results showed that LSAS scores were not significantly correlated with any Validity Scores for participants in the ASD or Control Groups, all *r*'s < .3, all *p*'s > .18, or across all participants, all *r*'s < .25, all *p*'s > .12.

Analysis

Images of houses were used as filler trials in this experiment so the participants did not view only faces and cars, but were not of interest to the research question and so were not included in the initial analyses. Validity scores for house cues did not differ between groups at either 100ms, *t*(40) = 0.82, *p* = .417, or at 800ms, *t*(40) = 0.49, *p* = .625.

A three way ANOVA was performed on the Validity Scores with factors of Cue (Face v Car), Time (100ms v 800ms) and Group (ASD v Control). There was a significant main effect of Cue, $F(1, 40) = 10.70$, $p = .002$, $\eta_p^2 = .21$, with Validity scores for face cues (*M* = 31.38) being higher than Validity Scores for car cues (*M* = 17.82). The main effect of Time was also significant, $F(1, 40) = 10.73$, $p = .002$, $\eta_p^2 = .21$, with Validity scores being greater when cues were presented for 100ms (*M* = 33.02) than 800ms (*M* = 17.82). There was also a significant interaction between Cue and Group, $F(1, 40) = 4.73$, $p = .036$, $\eta_p^2 = .11$ (see figure 8.1).

To explore this interaction, independent samples t-tests revealed no significant difference in validity scores to face cues between the ASD and control groups, *t*(40) = 0.50, *p* = .619, *d* = 0.16, or for car cues between groups, *t*(40) = -1.29, *p* = .203, *d* = -0.41. Paired samples t-tests showed that for the ASD group, Validity scores for face cues were significantly larger than for car cues *t*(19) = 3.33, *p* = .003, *d* = 0.74. For the control group, there was no significant difference between validity scores for face or car cues, *t*(21) = 0.92, *p* = .370, *d* = 0.20.

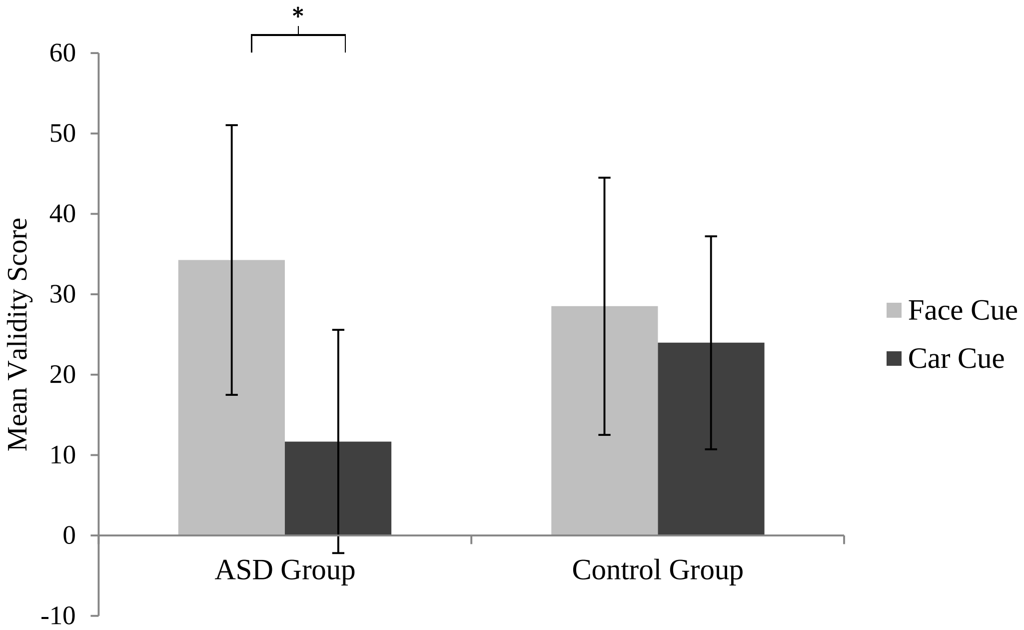


Figure 8.1. Mean validity scores for face and car cues for the ASD and Control Groups. Error bars show 95% confidence intervals of the mean.

To explore whether there were any differences in the initial orienting of attention to the cues, reaction times to valid trials were examined in a Group (ASD or Control) x Cue (Face or Car) x Time (100ms or 800ms) ANOVA. This revealed a main effect of Cue, $F(1, 40) = 9.28$, $p = .004$, $\eta_p^2 = .19$, with reaction times to valid face cues (535ms) being faster than to valid car cues (543ms). This suggests that all participants were faster to orient attention to a face cue than a car cue. No other main effects or interactions were significant, suggesting the only variable impacting on the speed of orienting attention to the cues in the present experiment was whether the cue was a face or a car.

Post hoc analysis

As the finding from the main ANOVA was in contrast to the majority of literature in the field in that the control participants were not found to be slower to disengage from faces than cars, but the ASD group were, post hoc analyses including the filler house stimuli were conducted to explore whether this pattern extended to other non-social stimuli. The initial three way ANOVA described above was performed again on the Validity Scores with factors of Cue (Face, Car or House), Time (100ms v 800ms) and Group (ASD v Control). Once again, there was a main effect of Cue, $F(2, 80) = 6.86$, $p = .002$, $\eta_p^2 = .15$, with validity scores for faces cues (mean = 31.38) being larger than either car (mean = 17.82) or house cues (mean = 16.63), and a main effect of

Time, $F(1, 40) = 11.20$, $p = .002$, $\eta_p^2 = .22$, with validity scores being greater at 100ms than 800ms. Additionally, the Cue by Group interaction was still significant, $F(2, 80) = 3.18$, $p = .047$, $\eta_p^2 = .07$. As in the original ANOVA, no other main effects or interactions were significant.

Collapsing the validity scores to face, car and house cues across presentation times, independent samples t-tests revealed that the ASD and Control groups did not differ on validity scores for faces, $t(40) = 0.50$, $p = .619$, $d = 0.16$, cars, $t(40) = -1.29$, $p = .203$, $d = -0.41$, or houses, $t(40) = 0.81$, $p = .423$, $d = 0.26$. However, within groups t-tests revealed that the ASD group had greater validity scores for faces than cars, $t(19) = 3.33$, $p = .003$, $d = 0.74$, but there was no significant difference between validity scores for faces and houses, $t(19) = 1.94$, $p = .068$, $d = 0.43$, or between cars and houses, $t(19) = -1.80$, $p = .089$, $d = -0.40$. For the Control group, Validity scores for faces were found to be significantly larger than for houses, $t(21) = 2.63$, $p = .016$, $d = 0.56$, but there were no significant differences between validity scores for faces and cars, $t(21) = 0.92$, $p = .370$, $d = 0.20$, or between cars and houses, $t(21) = 1.56$, $p = .133$, $d = 0.33$. Therefore the ASD group were slower to disengage attention from faces when compared to cars, but not when compared to houses, and the Control group were slower to disengage attention from faces when compared to houses, but not when compared to cars.

Due to this different pattern of disengaging attention in relation to the type of non-social stimuli, mean validity scores for both cars and houses were combined into a Non-Social validity score in order to compare disengagement from faces relative to non-social stimuli. Independent samples t-tests showed no difference between the ASD group and the Control group on validity scores to faces, $t(40) = 0.50$, $p = .619$, $d = 0.16$, or non-social cues, $t(40) = -0.24$, $p = .811$, $d = -0.08$. Within groups, paired sampled t-tests revealed the same pattern of faster disengagement from faces than non-social cues in both groups. Validity scores to faces were significantly larger than to non-social cues in the ASD group, $t(19) = 2.82$, $p = .011$, $d = 0.63$, and in the Control Group, $t(21) = 2.46$, $p = .023$, $d = 0.52$.

Discussion

The present study explored the disengagement of attention from faces and cars in participants with and without ASD using a peripheral cueing experiment. It was predicted that the control group would show slower disengagement from faces than cars, and the ASD group would not show this delay in disengaging from face stimuli. The results indicate that the opposite was true. The control group showed no difference in disengaging attention from face or car stimuli, and the ASD group were slower to disengage attention from face stimuli relative to car stimuli. A number of previous studies have found that typically developing controls are slower to disengage from face stimuli relative to ASD participants in gap overlap tasks (Chawarska et al., 2010; Kikuchi et al., 2011). The Social Motivation Theory of autism (Chevallier et al., 2012) would predict that individuals with ASD would not show a typical delay in disengagement from faces as people are not as intrinsically interesting and rewarding to them as in typical development. The current results were not consistent with this prediction and contrary to the majority of literature in this area. However, post hoc analyses revealed that whilst the ASD group were slower to disengage from faces than cars, they were equally as slow to disengage from faces as house cues. The control group showed an opposite pattern with regard to the non-social stimuli in that they were slower to disengage from faces than houses, but equally slow to disengage attention from faces as cars. This therefore suggests that faces are holding attention in both groups relative to non-social objects, and the disengagement from social stimuli is typical in ASD, but the non-social comparison stimuli are attended differently between groups.

Typical slowed disengagement of attention from faces in the ASD participants relative to non-social objects appears to be indicative of a top down attentional bias for social information in ASD as was seen in the control group. This suggests that individuals with ASD are interested in and motivated to attend to faces. However, other possible explanations may account for this seemingly intact element of social attention. Research exploring the disengagement of attention from faces in ASD has been mixed, and differences in results may be due to the methods used. Whilst Fischer et al. (2013) found no differences in the disengagement of attention from faces in ASD and typical development, Kikuchi et al. (2011) and Chawarska et al. (2010) have found no differences in disengaging attention from social and non-social stimuli in ASD. The results of the present study support Fischer et al. as typical delayed disengagement from faces relative to non-social stimuli was found. Whilst Chawarska et al.'s study was completed by toddlers, both Kikuchi et al. and Fischer et al. examined the disengagement of attention from faces in older children with ASD (9-12 years) therefore differences in age cannot account for the differences in results obtained from these studies. However, Fischer et al. (2013) did not find any difference in disengaging attention from social compared to non-social stimuli in the control group either, with no main effect of central stimulus type in their analysis. This therefore suggests that the stimuli were not capturing the general tendency for people to be slower to disengage attention from faces than other objects, and therefore group differences would not be illuminated. Therefore the results of Fischer et al. with regards to disengagement from faces are not comparable to those of the present study, which did find a difference in disengaging from faces relative to non-social stimuli in the typically developing control group.

Gap overlap tasks measure the disengagement of attention when a central and peripheral stimulus are both present on screen, with the dependent variable being the latency to fixate the peripheral stimulus. Longer latencies to fixate the peripheral stimulus are indicative of slowed disengagement from the central stimulus. Unlike gap overlap experiments, the present study presents one type of stimulus in isolation with no competing images. The peripheral cueing technique ensures that attention is exogenously drawn to the peripheral stimulus (Jonides, 1981).

Therefore this forces the participants to attend the face stimuli. The measure of disengagement then comes from the reaction time to identify a target that is presented at the opposite location to the attended stimulus. It could be the case that when a person with ASD is forced to attend a face, this may then hold their attention. However, Kikuchi et al. (2011) found that when participants with ASD were instructed to fixate on faces in a gap overlap task, they did not exhibit longer saccadic reaction times to look at the peripheral object than when the central image was a house, whereas the control group did. The ASD group only showed slowed disengagement from faces when they were instructed to attend the eye region of the faces. This suggests that generally allocating visual attention to a face is not enough to result in difficulty disengaging attention. However, Kikuchi et al. used a gap overlap task where two images are present on the screen. Despite being instructed to fixate on the face, participants may still have found the peripheral stimuli more interesting. Additionally, the participants showed slowed disengagement from faces when they fixated the eye region. Research has shown that individuals with ASD tend not to naturally look at the eye region of faces to such a great extent as in typical development (Pelphrey et al., 2002). Therefore it would be presumed that when a face image exogenously captures attention, there is no reason to expect that the ASD group would choose to orient to the eye region. However, the difference may come from the type of attention that was measured. The present study explored covert attention to peripheral cues whilst fixation was maintained on a central cross. Carrasco, Penpeci-Talgar, and Eckstein (2000) have demonstrated that attending to a stimulus covertly increases contrast sensitivity (in a typically developing population). Contrast is a feature of stimuli that captures attention in a bottom up manner, and individuals with ASD are found to allocate attention based more on bottom up features than top down processes, even when social information is salient (Amso et al., 2014). The eyes contain the greatest area of contrast within a face. Therefore it is possible that the covertly attended faces in the present study may have drawn the attention of the participants to the eye region. This could then lead to over arousal in participants with ASD. If the ASD group were orienting covertly toward the eye region, the direct gaze could have resulted in increased attention holding of the face stimuli. Kylliäinen and Hietanen (2006) found that direct gaze increased arousal in ASD relative to faces with averted gaze, a difference that was not found in typically developing participants, and Vogt et al. (2008) found that arousal modulates disengagement of attention with disengagement being slower the higher the arousal caused by the stimulus. Therefore, in summary, it is suggested that the longer disengagement latencies in the ASD group from faces relative to non-social stimuli are not necessarily the result of greater interest in the face stimuli relative to the car stimuli in that group, which would be inconsistent with the Social Motivation Theory and other literature regarding disengagement from social information in ASD. Rather they could be the result of bottom up processes being elicited by the covert peripheral attention cueing task in the ASD group which may essentially force their attention to the eye region of the faces resulting in increased arousal and slowed disengagement.

Alternatively, social anxiety may have influenced the longer disengagement from faces in ASD. Social Anxiety is frequently found to be higher in people with ASD than in the general population (Simonoff et al., 2008; White et al., 2012), and social anxiety scores were found to be higher among the ASD group than the control group in the present study. Social anxiety is found to be linked to difficulty disengaging attention from threatening stimuli (Buckner et al., 2010), and faces compared to other objects are found to be linked to attentional differences in sub clinical social anxiety (Garner et al., 2006). This therefore would strongly suggest that the difficulty disengaging attention from faces seen in the ASD group in the present study could be linked to social anxiety. However, correlations revealed no relationship between social anxiety and disengagement from face cues in either the ASD or control group. Therefore it is unlikely that greater social anxiety in those with ASD caused them to be slower to disengage attention from faces than non-social stimuli. Hollocks et al. (2013) suggest that anxiety in ASD may not be related to attentional biases to threat that are found to be related to anxiety in typically developing populations. This again suggests that the bias found in the ASD group in the present study to be slower to disengage from attention to faces may not stem from social anxiety.

As in previous studies within this thesis, there was no evidence to suggest that participants with ASD allocate attention preferentially to objects which may be of CI, as represented by images of cars in the present study. It was hypothesised that the ASD group may show longer disengagement latencies when invalid cues were car stimuli as they may be of more salience and reward to that group (as in Sasson & Touchstone, 2013). The reason that cars did not hold attention in the ASD group may be that they are not sufficiently representative of objects of CI. Whilst vehicles are frequently identified as objects of particular interest among CIs in ASD (Sasson, Dichter, & Bodfish, 2012; Turner-Brown et al., 2011), trains are often selected as the most salient exemplifier within this category for people with ASD (e.g. as in Fischer et al., 2013; Golan et al., 2010). In addition, vehicles may not be of interest to all people with ASD and more individualised stimuli ought to be used to investigate visual attention to objects of CI in ASD. Fischer et al. (2013) explored the disengagement of attention in ASD using a gap overlap task using social and non-social stimuli. Within the non-social stimuli, Fischer et al. included images of trains as a representative of a category of objects that may be of particular interest to people with ASD to explore whether items which may be of more interest impact upon social attention. The type of non-social stimuli (trains or fruits) did not result in disengagement differences across groups. This suggests that these particular objects of CI were not leading to impaired disengagement as in the studies from Sasson et al., where differences in social attention were found depending on whether the non-social stimuli presented with them were of CI or not. This finding may differ from that of Sasson and Touchstone (2013) and Elison, Sasson, Turner-Brown, Dichter, and Bodfish (2012) because only one type of object related to CIs in ASD was represented, whereas Sasson and Touchstone and Elison et al. used a number of different objects relating to CIs. Future research would benefit from exploring individual areas of CI and creating stimuli to match these rather than taking the broad, research based approach to selecting stimuli relating to CIs that the present study took.

Indeed the car stimuli appeared to be particularly non-salient to the ASD group as they were found to be slower to disengage from faces than cars, but not from houses. Through both the Dot Probe task in the previous chapter and the present experiment, the house stimuli appear to capture attention to a greater degree than the car stimuli in the ASD group. It is suggested that this is the result of differences in complexity of these two stimuli, and a bias for attention to be driven by more bottom up features of the stimuli in ASD (Maekawa et al., 2011). The very simple images of cars may not have had any features that particularly held attention in the ASD group. Whilst car stimuli were chosen with good reason based on previous research identifying vehicles as objects of CI in ASD and their configural similarity to faces, due to these potential problems with the car stimuli both in their visual properties and in whether they truly represent CIs in ASD, conclusions cannot be drawn as to whether objects of CIs do hold attention differently in ASD relative to typically developing controls.

No differences were found in validity scores in relation to the time course of stimulus presentation and ASD or control groups, contrary to predictions. This contradicts the findings of Townsend, Harris, et al. (1996) who found a greater benefit of a valid cue in a peripheral cueing experiment when presented for 800ms in the ASD group relative to 100ms, at which time control participants showed the greatest benefit from valid cues. However, the findings of the present study seem to support those of Iarocci and Burack (2004) who found no difference in the benefit of peripheral cues in ASD and control groups using a short SOA of 200ms. Overall, the present study found that cues presented for 100ms produced longer disengagement times than 800ms. This is most likely because inhibition of return is likely to facilitate responses to targets presented at the uncued location after presentation times of 300ms (Klein, 2000).

Chapter 5 found no differences in disengaging attention between those with high and low levels of autism traits, with all participants being slower to disengage attention from faces compared to cars. This is comparable to the result of the present study that both the ASD and control groups were found to be slower to disengage attention from faces relative to non-social stimuli. This suggests that when attention is exogenously forced to engage on a face, there are no differences in how this face holds attention between those with and without ASD, and in the subclinical autism spectrum. The present study deliberately utilised reductionist methodology by presenting one image at a time using a method that ensured the engagement of attention on the image. This ensured that each image was attended to so that disengagement from that image could be measured without any confounds of other images competing for attention, as in the gap overlap task. However, it does not provide evidence as to whether faces would hold attention in a more naturalistic setting. It does show that individuals with ASD can prioritise faces relative to non-social stimuli in attention when the task forces them to attend to faces. Therefore this suggests that faces do hold attention when nothing else in the visual field is competing for attentional resources, but it is possible that when other objects compete, as in the gap overlap tasks used by Kikuchi et al. (2011) and Chawarska et al. (2010), then faces do not receive this priority. This is explored in Chapter 9 using eye tracking and free viewing of natural scenes.

Finally, it was found that, when looking at the reaction times to validly cued stimuli and therefore the time taken to orient attention, all participants were faster to orient to face stimuli than car stimuli. This suggests that the participants with ASD were faster to orient towards faces than other stimuli to the same degree as the control participants. It is possible that this result, which stands in contrast to the reduced selective attention orienting bias towards faces found in Chapter 7 in the ASD group, is the result of the face being presented in isolation. The peripheral cueing task forces attention to the peripheral stimulus, and no other stimuli are competing for visual attention. This methodology therefore was not exploring selective attention towards faces as the dot probe task in Chapter 7 did. The difference in results regarding the orienting of attention to faces between Chapter 7 and the present chapter suggests that when social information is presented in isolation, and attention forced to orient towards it, people with ASD attend typically to social information, as has been argued by Moore et al. (2015). However, when attention is under volitional control, other stimuli in the visual field may distract attention away from social information in ASD. This could either be a result of reduced social motivation in ASD (Chevallier et al., 2012), or potentially as a result of enhanced attention to details rather than interpreting the global meaning of stimuli when they are presented among a more complex visual field (Happé & Frith, 2006).

In conclusion, the present study found those with ASD took longer to disengage attention from faces compared to cars whereas the control group did not. This was contrary to the hypothesised results based on the Social Motivation Theory of Autism and previous research exploring disengagement of attention from faces in ASD. However, post hoc analyses including the filler house cues revealed that both groups were slower to disengage attention from social than non-social stimuli. This suggests that the ASD group demonstrate slowed disengagement from faces as in typical development. Given previous research which has found differences in disengaging and other elements of attention to faces in ASD, it is suggested that there may be different mechanisms involved in the holding of attention by faces in ASD rather than an intrinsic interest in social information. There was no evidence to suggest that cars, as a potential exemplar of CIs in ASD, were effective in capturing and holding attention in people with ASD. It is suggested that this may be because of properties of the stimuli or that they may not have effectively captured CIs for people with ASD.

Chapter 9

Attention to Social and Mechanical Objects in Natural Scenes in ASD

Chapter Abstract: The present study used eye tracking to explore overt visual attention to social and mechanical objects in natural scenes. Chapter 6 found that higher levels of subclinical autism traits are related to smaller amounts of time spent fixating on social elements of scenes. The present study similarly found that those with ASD spend less time fixating in social areas, are slower to fixate in social areas, and have shorter fixations on social objects than the Control group. Additionally, the ASD group were found to spend more time fixating on the background of scenes. These findings support previous research which has found social attention differences in ASD, and the greater amount of time spent fixating on extraneous information is suggested to link to atypical attention patterns in ASD driven by bottom up salience.

Chapters 7 and 8 found differences in attentional measures relating to orienting and disengaging attention from social and mechanical stimuli in ASD. This led on from findings of attentional differences in those with high levels of autism traits who showed a similar difference in the orienting of attention to faces relative to those with low levels of autism traits in Chapter 4, and who were found to spend less time fixating on social elements of natural scenes in Chapter 6. Measuring overt gaze behaviour with eye tracking adds to these findings by exploring whether the same pattern that is shown in covert attention translates to overt visual attention. Additionally, the dot probe and peripheral cueing tasks presented social and mechanical images in isolation. Eye tracking measures taken whilst viewing everyday scenes provide a more ecologically valid exploration of where participants allocate visual attention. Chapter 6 used eye tracking with people higher and lower in autism traits and found that higher levels of autism traits were associated with lower proportions of time fixating on social components of scenes. The present chapter investigates whether similar results are observed in those with a clinical diagnosis of ASD.

Eye tracking is often used to assess whether people with ASD spend the same amount of time looking at social elements of scenes as typically developing controls (e.g. Fletcher-Watson et al., 2009; Riby & Hancock, 2008) or whether people with ASD show a typical attentional preference for looking at the eye region of faces (Fletcher-Watson et al., 2009; Freeth et al., 2010). Using eye tracking to measure fixations provides an indication of where they are looking to gain more information (Boraston & Blakemore, 2007), and thereby provides a measure of what is of interest to the viewer. Despite the growing body of eye tracking research investigating social attention in ASD, there is no consensus as to whether social attention is typical (Guillon et al., 2014), with studies to date often producing conflicting and mixed results.

In one of the earliest eye tracking studies to investigate social attention in ASD, Klin et al. (2002) found that participants with ASD fixated more on non-social objects than control participants and less on eye regions than control participants when viewing movie clips containing people. The authors suggested that social information is less salient to people with ASD. This finding was corroborated by Riby and Hancock (2009a) using static images containing faces embedded in natural scenes and scrambled pictures containing faces. It was found that the ASD group were slower to look at the faces in scenes, looked less at them, and fixated for shorter durations than the control and Williams' Syndrome groups. The authors link a reduction in social attention with decreased opportunities to learn social skills in the ASD group, and suggest that the reduced social attention is a result of diminished interest in social information. Using more naturalistic images of social scenes (e.g. a wedding, a group of people talking), Riby and Hancock (2008) found that people with ASD spent less time fixating on people and faces within the scenes than the typically developing and Williams Syndrome comparison groups. Bird, Press, and Richardson (2011) presented participants with video clips from a TV series and a newsreader. It was found that autism symptom severity was negatively correlated with fixations on faces in the clips. Taken together these studies suggest that social attention is atypical in ASD, characterised by a reduction in attention to faces and the eye region in particular. The implications of this are that face expertise may not develop in individuals with ASD and this could lead to difficulties interpreting social cues and reading emotions (Dawson, Webb, Wijsman, et al., 2005).

However, many studies also report that visual attention to social information is typical in ASD. van der Geest, Kemner, Camfferman, Verbaten, and van Engeland (2002) presented participants with cartoon drawings of scenes containing people. It was found that the ASD and control groups both fixated more on the person within the scenes than other objects and did not differ in the amount of time fixating the person or how many times they fixated it. This suggests that social attention may be typical in ASD. Additionally, Gillespie-Smith et al. (2013) presented 13 year old children with images from the Picture Exchange Communication System (PECS) containing faces and other objects. The children with ASD were found to fixate faces equally as fast as the control groups and to spend as much time fixating on the faces as the control groups. This seems to suggest that the children with ASD were demonstrating typical social attention when viewing simplistic drawings of faces. Using photographs of people rather than cartoons, Fischer et al. (2013) found that both ASD and control participants were equally fast to fixate on a face when used as a peripheral stimulus in a gap overlap task. There was also no group difference in the total looking time to the faces. Similarly, Parish-Morris et al. (2013) found no group differences between ASD and control participants in viewing faces when presented with other objects. These research findings appear to suggest that social attention is typical in ASD, contrary to the research highlighted above. One of the main reasons for this discrepancy may be the type of stimuli used. The majority of studies which found a difference in visual attention to faces in ASD used movies or natural scenes (Klin et al., 2002; Riby & Hancock, 2008), whereas those that found no difference utilised cartoon images or faces presented in isolation with no visual context or background.

However, the results when using naturalistic scenes are not always consistent either. Some studies have reported mixed results, depending on the eye tracking measure that is analysed. Fletcher-Watson et al. (2009) found that participants with ASD spent a similar proportion of viewing time on the person appearing within a complex scene in the stimuli used. However, when examining the first fixations made by participants within the scenes, it was found that the ASD group fixated the person first significantly less than the control group. This suggests that although people with ASD may attend to social information overall with a comparable time to controls, the social information does not receive the same attentional priority and immediately capture interest when viewed within a natural scene. Similar results were found by Freeth et al. (2010), as they reported that ASD and control groups spent a similar proportion of time fixating the face in natural scenes containing a person. However, the control group was faster than the ASD group to initially fixate on the face, and spent more time viewing the top half of the face during the first part of viewing than the ASD group. The results from these two studies suggest that although social attention may sometimes appear typical in ASD when looking at overall looking time, group differences are apparent with measures looking at the priority that social information is given within attention suggesting that social attention is atypical in ASD.

In addition to research looking at social attention in ASD, in light of the Social Motivation Theory of autism (Chevallier et al., 2012), whereby individuals with ASD may not be motivated to attend to social stimuli, research is beginning to investigate visual attention to other objects which may be of more interest to people with ASD. The EMB theory of autism (Baron-Cohen, 2002) and research investigating the content of CIs suggest that mechanical objects may be of greater attentional interest to people with ASD. To examine visual attention to objects of CI in ASD, Sasson et al. (2008) presented children with and without ASD with object arrays containing social and non-social objects and used eye tracking to measure fixations. The non-social content included items related to CIs, such as vehicles, and items not related to CIs such as clothes. Compared to control children, those with ASD looked at fewer objects, fixated for longer, and fixated more times on objects they gazed at. However, there were no group differences in relation to the object categories in the study, with both the ASD and control groups fixating more on the social objects (i.e. people). However, a trend was found for the ASD group to attend less to the social objects when objects of CI were also in the array, compared to when neutral objects were present. Sasson and Touchstone (2013) investigated this further by presenting pairs of social and non-social stimuli and again using eye tracking to measure fixations. The children with ASD attended less to faces than controls when faces were paired with items related to CIs, but to the same extent as controls when faces were paired with objects not related to CIs. The authors suggest that paying too much attention to objects of CI may mean that people with ASD pay less attention to people, which may impact on social development. However, Parish-Morris et al. (2013) found no difference between children with ASD and control participants in attention to objects termed 'high salience' in ASD. They presented participants with four dynamic images on screen, two social and two non-social, and used eye tracking to explore looking behaviour. The social stimuli were faces, one with direct gaze and one looking away. The non-social objects were of high salience, e.g. a bulldozer, or low salience, e.g. clothes. As well as the aforementioned finding that attention to faces was comparable for both groups, the high salience non-social objects were more interesting than anything else for both the ASD and control groups. This may be due to the specific stimuli that were used being particularly engaging for children and producing a ceiling effect. Therefore it cannot be concluded that the relevance of the competing non-social objects to CIs did not impact on attention to faces. Taken together, the results from these three studies exploring visual attention to objects related to circumscribed attention in autism are mixed. Once again, the type of stimuli used varied between tasks and none of these studies used naturalistic scenes.

The mixed findings in relation to both social attention and in attention to objects of CI in ASD may be due to differences in the types of stimuli being used. Studies have used videos (Klin et al., 2002), natural social scenes (Riby & Hancock, 2008), images of faces out of context (Riby & Hancock, 2009a), faces in isolation (Fischer et al., 2013) and object arrays (Sasson et al., 2008). The majority of research which has found atypical social attention in ASD has come from studies which used more natural stimuli, and Hanley et al. (2013) emphasise the importance of using more realistic stimuli when investigating visual attention.

The present study adds to research by Sasson and Touchstone (2013) and Sasson et al. (2008) by using eye-tracking to explore visual attention to people and to objects of CI in ASD in more naturalistic scenes. This provides a more ecologically valid measure of whether either category of object preferentially captures attention in ASD than some previous research. Whilst there have been some attempts to use natural scenes to explore social attention in ASD (e.g. Freeth et al., 2010; Hanley et al., 2013; Riby & Hancock, 2008), these have not directly compared attention to social information and attention to objects that might be of CI in ASD. The present study measured visual attention to people and mechanical objects in scenes from everyday life using the three different dependent measures frequently used in eye tracking research as described in chapter six. These were the latency to first fixate on social, mechanical or other areas of the scene, related to the initial orienting element of attention; the mean duration of each fixation, related to disengaging attention; and the overall amount of time spent fixating in each area of interest.

The aim of the present study was to investigate attentional preference for social or mechanical objects when viewing static scenes of everyday life in people with and without ASD.

Based on theory and previous research it was hypothesised that the ASD group would spend less time overall fixating on the social components of the scenes, and a greater amount of time fixating on the mechanical objects within scenes than the control group. It was predicted that the ASD group would be slower to first fixate on social elements of scenes than controls, and faster to mechanical. It was further hypothesised that the fixations of those with ASD may be more perseverative than controls on the mechanical objects within the scenes and less perseverative on the social elements.

Methods

Participants

Eye tracking data was collected for 13 of the participants with ASD described in chapter 7, and 13 of the control participants (see Table 9.1 for demographic information). The other participants recruited for the research presented earlier either declined to further take part in this study due to time constraints, or it was not possible to complete a successful calibration. Data was excluded for one participant from the ASD group because they did not move their fixation from the location of the central fixation cross at all throughout the presentation of scenes, apart from one saccade to a mechanical object in one scene. This left 12 participants with a diagnosis of an ASD and 13 control participants. Groups did not differ in age, IQ or sex ratios (see Table 9.1). One member each of the control and ASD group identified themselves as Chinese, one control identified themselves as Indian, and the remainder of participants identified as white European.

Table 9.1

Demographic information and mean questionnaire scores (SD) for participants included in analyses.

	ASD (n = 12)	Control (n = 13)	Comparison Statistics
Age	27.75 (9.31)	27.38 (6.63)	$t(23) = 0.11, p = .910$
Males: Females	7:5	8:5	$\chi^2(1, N = 25) = 0.03, p = .870$
IQ	112.18 (7.52)	114.46 (7.46)	$t(23) = 0.74, p = .456$
Verbal IQ	110.00 (9.57)	109.62 (13.38)	$t(23) = -0.08, p = .935$
Performance IQ	112.08 (6.51)	116.38 (5.91)	$t(23) = 1.73, p = .097$
AQ**	32.42 (8.68)	16.46 (6.32)	$t(23) = -5.29, p < .001$
SAS**	70.00 (31.96)	32.92 (12.78)	$t(23) = -3.87, p = .001$

*** Scores significantly differ across groups, p < .001*

One of the ASD group had a diagnosis of high functioning autism, and the remaining 11 had a diagnosis of Asperger's Syndrome. The mean AQ score for the ASD group in the present study (mean AQ = 32.42) was similar to groups in previous ASD samples (mean AQ = 35.8 (Baron-Cohen, Wheelwright, Skinner, et al., 2001), no significant difference between present sample mean and Baron-Cohen et al's sample mean, $t(11) = -1.35$, $p = .204$). The mean AQ score for the ASD group was also significantly higher than for the control group (see Table 9.1). Four of the participants with ASD reported comorbid psychiatric diagnoses of OCD, ADHD, anorexia and anxiety, as was discussed in Chapter 3.

Stimuli and Procedure

Stimuli and procedure were the same as that used in Chapter 6. Participants viewed 15 scenes containing social and mechanical elements for 5s each with a central fixation cross presented for 300ms between each scene. They were instructed to view the scenes as naturally as possible and an ASL D6 eye tracking camera using corneal reflection recorded where they were looking on the screen (see Chapter 6 for more information). Participants additionally completed the WASI to measure IQ as described in chapter 7, and the AQ and LSAS to measure autism traits and social anxiety as described in Chapter 4.

Results

Data Preparation

Data for scenes where pupil detection loss occurred (e.g. because of blinking or head movement) for over 50% of the time were discarded. This accounted for a total of 6 scenes in the entire experiment involving only 3 of the participants across both groups (1.71% of all data). Fixations were calculated by ASL Results Plus with the same threshold criteria described in Chapter 6.

Three dependent variables were created to explore visual attention to social and mechanical objects in those with and without ASD. (1) The total amount of fixation time spent within Social AOIs and within Mechanical AOIs was calculated for each scene for each participant and a mean was computed for each AOI type for each participant. This was used to relate to overall selective attention preference. (2) The time to make a first fixation within each AOI were used as a measure of what area of the scenes participants were initially drawn to, or the orientation of attention. Fixations beginning within 80ms from the onset of the image were not included in analyses as it is suggested that saccade latencies less than 80ms from the onset of a stimulus are likely to be anticipatory (Findlay & Walker, 1999), and face directed saccades can occur in as little as 100ms (Crouzet et al., 2010). (3) Finally, the mean duration of each fixation, in milliseconds, within each category of AOI was computed for all participants. This was used to relate to the disengagement of attention.

Social anxiety

LSAS scores were once again included as some research has suggested that social anxiety might influence social attention (Chen et al., 2002; Garner et al., 2006). Correlations between social anxiety and the three eye tracking measures of interest for Social AOIs were conducted to explore whether LSAS scores related to fixations in social AOIs. Two tailed Pearson's correlations revealed no significant relationships between LSAS scores and amount of fixation time in Social AOIs, latency to first fixations in Social AOIs, or the mean duration of fixations within Social AOIs in either the ASD or control group, or across both groups, all *r*'s < .46, all *p*'s > .12.

Dependent Variable 1: Overall Fixation Time

The mean overall fixation time spent within each AOI across scenes was calculated for each group (see Table 9.2). The mean total fixation time in social AOIs, in mechanical AOIs and outside the AOIs were all found to be normally distributed, with Q-Q plots and histograms following a normal distribution. This was confirmed by non-significant Shapiro Wilk tests for all three variables for each group, all *W*'s > .90, all *p*'s > .120. No outlying data points were identified (all *Z*s < 3.29).

Table 9.2

Mean time spent fixating within each AOI in ms (SD) for ASD and Control groups

	ASD (*n* = 12)	Control (*n* = 13)
Total time fixating in social AOI*	1012 (367)	1687 (299)
Total time fixating in mechanical AOI	1262 (400)	1233 (233)
Total time fixating outside AOIs*	1540 (383)	1062 (235)

** indicates significant difference at p < .01*

A 2 way ANOVA was run on the amount of fixation time data with AOI (Social v Mechanical v Outside) and Group (ASD v Control) as the factors.

There was no main effect of AOI, $F(2, 46) = 0.53$ $p = .593$, $\eta_p^2 = .02$, or of Group, $F(1, 23) = 0.86$, $p = .364$, $\eta_p^2 = .04$. The Group x AOI interaction was significant, $F(2, 46) = 17.16$, $p < .001$, $\eta_p^2 = .427$.

Independent samples t tests showed the ASD group spent a significantly smaller amount of fixation time within Social AOIs than the Control group, $t(23) = 5.06$, $p < .001$, $d = 2.11$ (see Figure 9.1). There was no difference between groups in the amount of fixation time within the mechanical AOIs, $t(23) = -0.22$, $p = .827$, $d = -0.09$. Participants with ASD spent a significantly greater amount of time fixating outside either AOI than the Control group, $t(23) = -3.80$, $p = .001$, $d = -1.58$.

Paired samples t tests showed that Control participants spent a significantly greater amount of fixation time in the Social AOIs than the Mechanical AOIs, $t(12) = 3.88$, $p = .002$, $d = 1.12$. For the ASD Group, there was no significant difference between the amount of fixation time spent in Social AOIs and in Mechanical AOIs, $t(11) = -1.43$, $p = .181$, $d = -0.43$ (See Figure 9.2 for group heat maps). Control participants spent a significantly greater amount of time fixating within Social AOIs than outside either AOI, $t(12) = 4.68$, $p = .001$, $d = 1.35$, but did not differ in their amount of fixation time within the Mechanical AOIs or outside either AOI, $t(12) = 1.65$, $p = .125$, $d = 0.48$. Contrastingly, the ASD group spent a significantly greater amount of time fixating outside either AOI than within the Social AOI, $t(11) = -3.40$, $p = .006$, $d = 1.03$. Again, the ASD group did not differ in the amount of fixation time in the Mechanical AOI or outside either AOI, $t(11) = -1.80$, $p = .098$, $d = -0.54$.

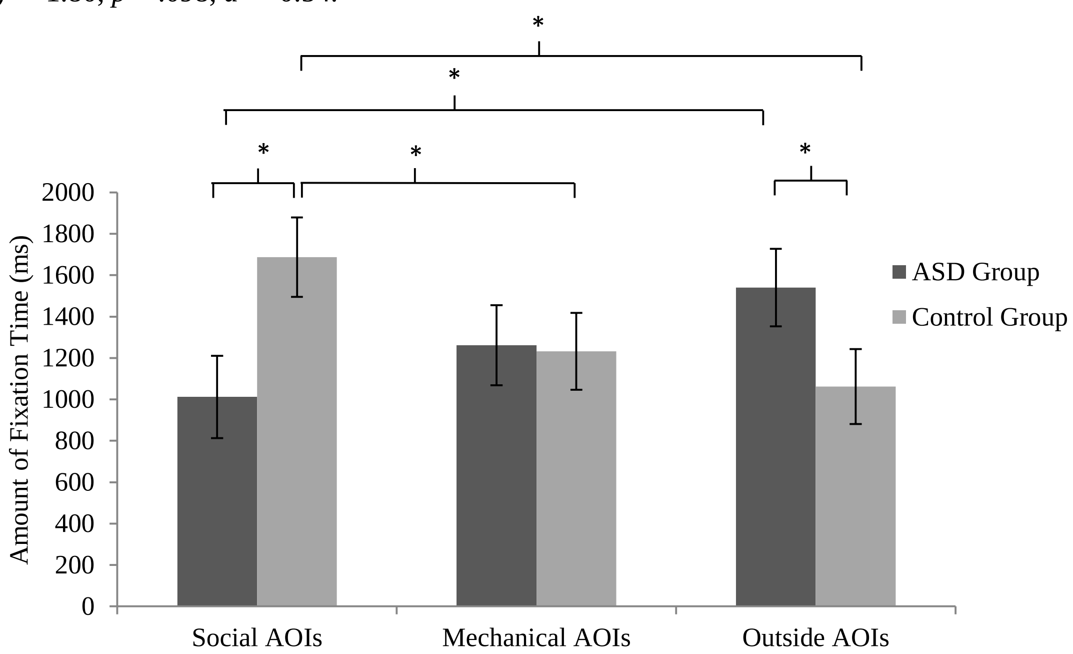


Figure 9.1. Mean fixation time spent in each AOI for ASD and control groups. * indicates a significant difference. Error bars show 95% confidence intervals of the mean.

a)

b)

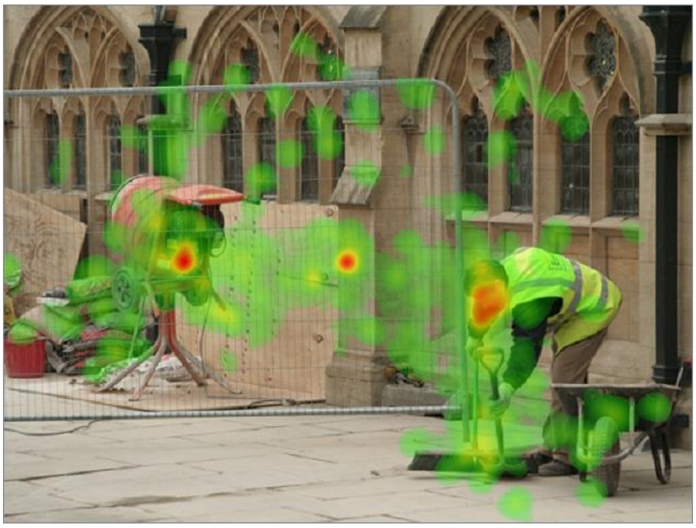


Figure 9.2. Cumulative heat maps for one scene for a) ASD and b) Control groups. ‘Hot spots’ indicate greater looking time to that area. Note that for the control group there is a stronger hot spot over the man’s head in the scene.

Dependent Variable 2: Latency to first fixations

The proportion of first fixations within each AOI for each group were initially explored and compared using independent samples t-tests as this data was not suitable for ANOVA analysis (see Table 9.3). This is for illustrative purposes as an addition to the latency to first fixations in order to further explore where attention was initially oriented. The proportions of first fixations show that the ASD group had significantly fewer first fixations in Social AOIs, and significantly more first fixations in the Mechanical AOIs than the Control Group.

Table 9.3. *Mean percentage of first fixations within each AOI (ms) for ASD and Control Groups (SD)*

	ASD (n = 12)	Control (n = 13)	Comparison Statistics
Social AOI	43.24	59.35	$t(23) = 2.76, p = .011$
	(16.91)	(12.09)	
Mechanical AOI	33.39	20.64	$t(23) = -2.71, p = .012$
	(14.72)	(8.08)	
Outside AOIs	23.38	20.01	$t(23) = -0.74, p = .468$
	(12.39)	(10.44)	

The mean time to first fixate within social and mechanical AOIs, and outside either AOI was computed (see Table 9.4). The mean time to first fixate within mechanical AOIs and outside either AOI was found to be normally distributed for both groups (for the control group, $W(13) = .977$, $p = .960$ for mechanical AOIs, and $W(13) = .911$, $p = .187$ for outside AOIs; for the ASD group, $W(12) = .951$, $p = .657$ for mechanical AOIs, and $W(12) = .968$, $p = .892$ for outside AOIs). However, the mean time to first fixate within Social AOIs were found to violate the assumption of normality for both the control group, $W(13) = .804$, $p = .008$, and the ASD group, $W(12) = .836$, $p = .025$. Observation of the histograms for this variable showed that the data was positively skewed for both groups, with the high frequencies of observations at shorter latencies. As this violation of normality was the result of a pattern in the data rather than one influential outlying case, the data for all three variables was transformed using the Log transformation. A two way mixed ANOVA was performed on the transformed data and the same results were obtained as when performed on the untransformed data. Therefore the analysis with the untransformed data is presented below for ease of interpretation, and the ANOVA with log transformed data is presented in Appendix VII. No outlying data points were identified (all Zs < 3.29).

Table 9.4

Mean latency to first fixations in each AOI for ASD and Control groups (ms)

	ASD (n = 12)	Control (n = 13)
Mean latency of first fixations in social AOI (*SD*)*	1382 (580)	624 (246)
Mean latency of first fixations in mechanical AOI (*SD*)	1419 (528)	1547 (391)
Mean latency of first fixations outside AOIs (*SD*)*	1710 (580)	2174 (509)

* indicates significant difference between groups

A Group (ASD or Control) x AOI (Social, Mechanical or Outside) ANOVA was performed on the latency to first fixate data. There was a main effect of AOI, $F(2, 46) = 20.96$, $p < .001$, $\eta_p^2 = .48$. Overall participants were found to be faster to fixate with the Social AOIs than the Mechanical, $t(24) = -2.84$, $p = .009$, $d = -0.58$, and Outside either AOI, $t(24) = -5.10$, $p < .001$, $d = -1.04$, and faster to fixate within the Mechanical AOI than Outside either AOI, $t(24) = -3.39$, $p = .002$, $d = -0.69$. There was no significant main effect of Group, $F(1, 23) = 0.20$, $p = .658$, $\eta_p^2 = .01$, but the interaction between Group and AOI was significant, $F(2, 46) = 9.49$, $p < .001$, $\eta_p^2 = .29$ (see Figure 9.3).

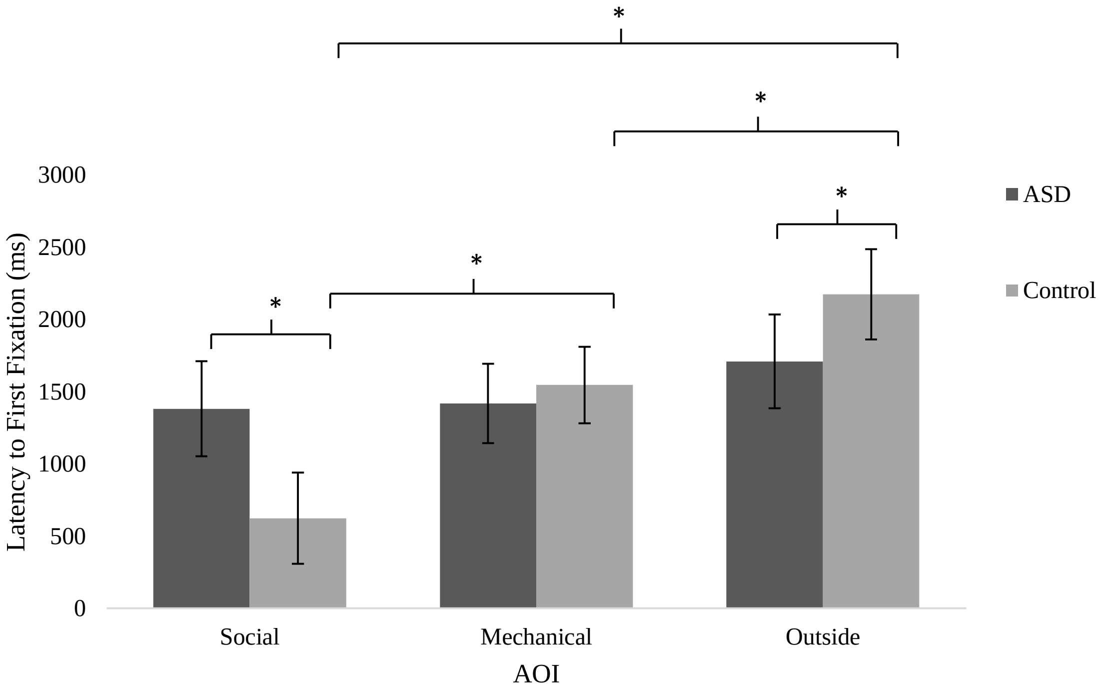


Figure 9.3. Mean latencies (ms) for first fixations with Social and Mechanical AOIs, and outside either AOI for ASD and Control groups. * indicates difference is significant. Error bars show 95% confidence intervals of the mean.

Exploring this interaction, independent samples t-tests revealed that the Control participants were significantly faster to fixate within Social AOIs than the ASD group, $t(23) = -3.44$, $p = .002$, $d = -1.43$. There was no significant difference between groups in the time taken to first fixate within Mechanical AOIs, $t(23) = 0.69$, $p = .497$, $d = 0.29$. The ASD group were found to be faster to fixate outside either AOI than the control group, $t(23) = 2.13$, $p = .044$, $d = 0.89$.

Paired samples t-tests revealed that the ASD group did not differ in the latency to make a first fixation within Social AOIs compared to Mechanical AOIs, $t(11) = -0.13$, $p = .902$, $d = -0.04$, or compared to outside either AOI, $t(11) = -1.20$, $p = .255$, $d = -0.36$, or between the latency to make a first fixation in Mechanical AOIs and Outside either AOI, $t(11) = -1.27$, $p = .229$, $d = -0.38$. However, the Control group were significantly faster to first fixate within Social AOIs than mechanical AOIs, $t(12) = -7.82$, $p < .001$, $d = -2.26$, and than outside either AOI, $t(12) = -12.80$, $p < .001$, $d = -3.70$. Additionally, the Control participants were faster to fixate within mechanical AOIs than outside either AOI, $t(12) = -4.05$, $p = .002$, $d = -1.17$.

Dependent Variable 3: Mean Fixation Duration

The mean duration of each fixation within each AOI and outside either AOI was computed (see Table 9.5). All were found to be normally distributed except for the mean fixation duration outside either AOI for the Control Group, $W(13) = .83$, $p = .014$. From observation of the histogram for this variable, it appears that this is due to one extreme value in the left side of the tail. However, this data point was not identified as an outlying data point, $Z = -2.78$. Log or square root transformations did not correct for this violation of normality. However, parametric testing proceeded owing to the robustness of ANOVAs to violations of normality (Schmider et al., 2010). This was backed up by non-parametric Mann Whitney U tests to explore between group comparisons, and Wilcoxon signed ranks tests to explore within group comparisons across the AOIs. The results of the non-parametric tests supported those of the main ANOVA (see Appendix VII).

Table 9.5

Mean duration of fixations in each AOI across groups. Values shown are in ms.

	ASD (n = 12)	Control (n = 13)
Average duration of each fixation in social AOI*	268 (35)	327 (49)
Average duration of each fixation in mechanical AOI	275 (34)	265 (31)
Average duration of each fixation outside of AOIs	280 (35)	260 (25)

* indicates significant difference between groups

A Group (ASD or Control) x AOI (Social, Mechanical or outside) ANOVA on the mean duration of each fixation found a main effect of AOI, $F(2, 46) = 7.94$, $p = .001$, $\eta_p^2 = .26$, with fixation durations longer in social AOIs (mean = 297ms) than mechanical (mean = 270ms) and outside (mean = 270ms). The main effect of group was not significant, $F(1, 23) = 0.76$, $p = .391$, $\eta_p^2 = .03$.

The Group x AOI interaction was significant, $F(2, 46) = 15.01$, $p < .001$, $\eta_p^2 = .40$. Independent samples t-tests showed that participants with ASD had shorter fixations in social AOIs than control participants, $t(23) = 3.45$, $p = .002$, $d = 1.44$ (see Figure 9.4). There was no significant difference in fixation durations in the Mechanical AOIs between Control and ASD participants,

$t(23) = -0.79$, $p = .44$, $d = -0.33$, or in the duration of fixations outside either AOI, $t(23) = -1.64$, $p = .115$, $d = -0.68$.

Paired samples t-tests showed that for the ASD group, there were no differences in the duration of fixations within any AOIs or outside, all t's < -1.4, all p's > .19.

For control participants, fixations in Social AOIs were significantly longer than in Mechanical AOIs, $t(12) = 5.32$, $p < .001$, $d = 1.54$, and than outside either AOI, $t(12) = 5.60$, $p < .001$, $d = 1.62$. There was no significant difference in the length of each fixation in the mechanical AOIs and outside either AOI, $t(12) = -0.46$, $p = .654$, $d = -0.13$.

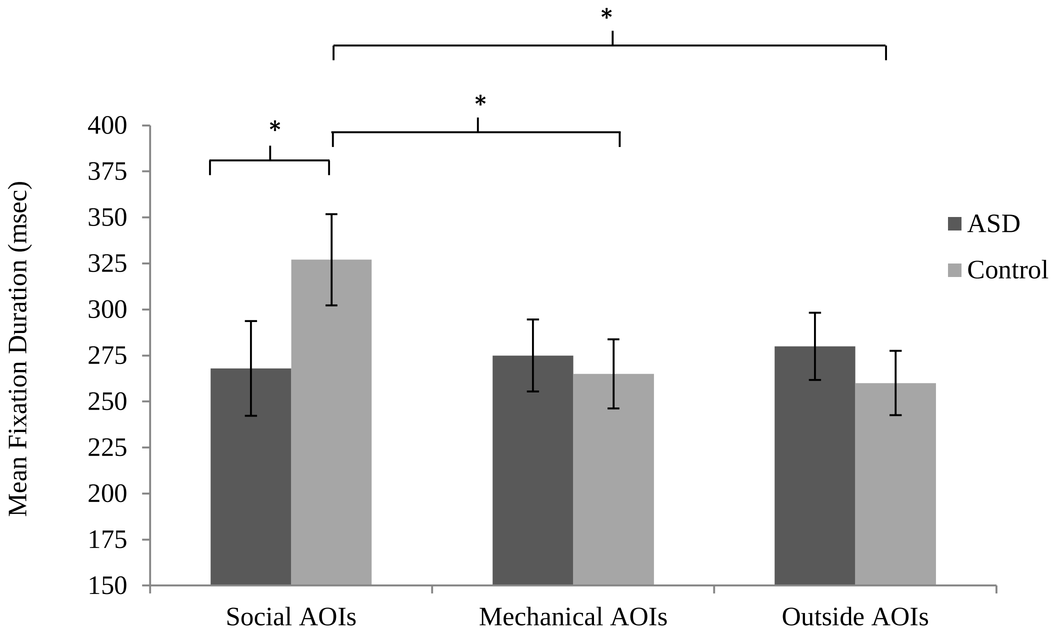


Figure 9.4. Mean fixation durations in each AOI for control and ASD groups. * indicates a significant difference. Error bars show standard error of the mean.

Discussion

The present study investigated whether ASD and control participants attended differently to social and mechanical elements within static natural scenes during free viewing. It was found that the participants with ASD spent less time overall fixating in social areas than controls; were slower to fixate first on the social element of the scenes than controls; and had shorter fixations on social elements as control participants. In addition, the ASD group were faster to fixate outside either social or mechanical areas than the control group, and did not differ in their latency to initially fixate social, mechanical or other areas of the scenes. The ASD group did not show a difference in the mean length of each fixation in social and mechanical areas or the amount of fixation time in each area. Together these results shows that the ASD group were not prioritising social information in the same way as the control group, and that for those with ASD there was no difference in attentional priority towards social or mechanical items within everyday scenes. Additionally, the ASD group spent a significantly greater proportion of fixation time outside the areas of interest than the control group, consistent with clinical reports that individuals with ASD tend to look at extraneous items in the environment (e.g. Kanner, 1943).

The control group were faster to fixate within social AOIs than the ASD group, and were quicker to fixate in the social areas than mechanical. The reduced orienting of attention to social information in ASD suggests that social information is less salient to them, and so is less likely to automatically capture their attention. The present result of reduced orienting to social information within a scene differs to those of Fischer et al. (2013) who found typical social orienting in ASD. Fischer et al. (2013) used the gap overlap task and although this also measures overt visual attention with eye tracking, there is a difference in the way the images are presented. The gap overlap task presents two images in isolation and without context. The present study showed participants naturally occurring scenes that contained people. It could be that when there are only two images competing for attention people with ASD may demonstrate a typical attention pattern towards social images, but when they are placed within a broader context they do not immediately capture attention. This finding is similar to those of Freeth et al. (2010) and Fletcher-Watson et al. (2009) who found participants with ASD were slower to initially fixate the face of a person during eye tracking whilst viewing natural scenes than control participants. The results supported the hypothesis that participants with ASD would not be as immediately drawn to the social elements of scenes as the control group. This finding would be predicted by the Social Motivation Theory of autism which suggests the people with ASD do not exhibit a typical drive to orient preferentially towards social information (Chevallier et al., 2012). It also supports the findings of Chapter 7 where the ASD group was not found to demonstrate a true attention orienting bias towards faces in the dot probe task.

When examining the overall amount of fixation time in each AOI, the ASD group appeared to be drawn to more extraneous aspects of the scenes, spending the longest amount of time fixating outside either social or mechanical areas. This suggests that neither social nor mechanical objects were of greater interest to the ASD participants. This supports findings that toddlers with ASD show greater attention to non-social objects than comparison groups and less to social (Swettenham et al., 1998). Ozonoff et al. (2008) found that 12 month old infants who later receive a diagnosis of ASD were more likely to display unusual visual attention to objects than comparison groups, including prolonged visual inspection. Similarly, Zwaigenbaum et al. (2005) found increased visual attention to non-social objects in the environment in 12 month old infants who were later diagnosed with autism. The present findings that the ASD group spent a greater proportion of their fixation time outside the social and mechanical AOIs and spent equal amounts of time fixating social and mechanical elements of scenes adds to this literature of atypical visual attention to objects. The findings suggest that atypicalities in infancy may persist into adulthood. Research which displays faces in isolation has indicated that in this case, individuals with ASD may show typical social attention (e.g. Fischer et al., 2013). However, in complex natural scenes where there may be many distracting elements, it appears that people within the scenes do not capture or hold attention in ASD whereas they do in typically developed adults.

The control participants were found to have longer fixations on social elements of scenes than the ASD group, and longer fixations on social areas than their fixations on mechanical elements of scenes. This finding is similar to that of Riby and Hancock (2009a) who also found that those with ASD had shorter fixations to faces than typically developing controls. The authors suggest that this is because of a diminished interest in the faces relative to controls as disengagement of attention is linked to top down processes reflective of current goals and interests. Therefore if a person is more interested in a stimulus in their visual environment, longer fixations indicating slower disengagement would be expected. A similar interpretation could be made here as there were no task demands and participants were free to view the scenes as they wished. Therefore it can be inferred that when visual attention is under volitional control, people in scenes do not hold the attention of individuals with ASD due to a lack of social interest, in line with the Social Motivation Theory (Chevallier et al., 2012).

The finding that the ASD group had shorter fixations than the control group on social elements of scenes appears contradictory to the finding of Chapter 8 where the participants with ASD were found to show slowed disengagement from faces relative to other non-social stimuli to the same extent as control participants. This could be because of the nature of the stimuli. The peripheral cueing task presented faces gazing directly forward in isolation, and the present study presented people with varying angles of gaze and presented within a natural scene. Dalton et al. (2005) found that direct gaze lead to a heightened emotional response in people with ASD, and it is possible that this contributed to the slowed disengagement in the ASD group in Chapter 8. Alternatively, the larger amount of competing information in the visual field could have drawn attention away from the social elements of scenes in the present study.

In all three measures of visual attention in the present study, the ASD group demonstrated no difference in their attention to social or mechanical elements of scenes. Sasson and Touchstone (2013) found that the simultaneous presentation of objects of CI with faces elicited a reduction in visual attention to faces in children with ASD relative to when faces were paired with objects not of CI. It could be the case that the amount of fixation time to faces was reduced in the present study because the participants with ASD were drawn to the mechanical objects in the scenes. However, there was no difference between the control and ASD groups in the amount of fixation time on mechanical objects in scenes. The mechanical items did not hold attention over the course of the five second viewing time differently to controls. The EMB theory of autism (Baron-Cohen, 2002) coupled with research around CIs in ASD (e.g. South et al., 2005) would suggest that the participants with ASD would be less interested in social elements of scenes and more interested in the mechanical elements (representing closed systems). This was not found to be the case. It would be worthwhile to present natural scenes containing neutral objects as well, as in Sasson and Touchstone (2013), whilst controlling for the content of the background, to compare social attention in ecologically valid stimuli when there are competing objects of high and low interest. Whilst the scenes used in the present study exhibited a variety of mechanical objects, thereby improving on the limited use of cars only in the peripheral cueing and dot probe tasks in earlier chapters, it is still not necessarily the case that these objects actually were of particular interest to the ASD group. Although previous research has frequently identified vehicles as a category frequently of CI to people with ASD (South et al., 2005; Turner-Brown et al., 2011), they are not necessarily so for all people with ASD. It would have been interesting to measure the participants' ratings of their interest in the elements of the scenes to establish whether they were interested in people or mechanical objects, and whether this self-reported interest correlated with the eye tracking measures of visual attention.

However, it should be noted that comparison of the proportion of first fixations on mechanical objects within scenes revealed that participants with ASD initially fixated these objects more often than participants without ASD. This finding contrasted with the data regarding latencies of first fixations to mechanical objects where no difference was found between ASD and control groups. There was no group difference in the mean time to make first fixations, therefore the discrepancy in these two variables is not likely to be the result of slower fixation latencies in the ASD group which may render comparison across this variable unfeasible. Instead the difference may be the result of greater variability within the ASD group as demonstrated by larger standard deviations for both proportions of first fixations and latencies to first fixations compared to the Control group. Therefore some participants may have fixated mechanical objects first but been slower in doing this than the participants in the ASD group who fixated other objects first. This highlights the importance of careful selection of dependent variables when using eye tracking methodology to explore visual attention in ASD. Across all variables in the present study, the purely descriptive variable of proportion of first fixations variable was the only one found to highlight a difference between ASD and control participants with regards to mechanical objects. Therefore it is likely that the conclusions made from the other variables regarding attention to mechanical objects in ASD are valid, but there is potential support for increased attention to mechanical objects. This is worth exploring with the methodological improvements suggested for this throughout this thesis.

The present findings also differ to those of Parish-Morris et al. (2013) who presented participants with four images at once, two social and two non-social. The non-social objects were either of high salience (relating to CIs in ASD) or low salience. They found no significant group differences in total fixation duration, first fixation, or number of fixations in relation to visual attention to faces or objects. The results of the present study potentially differ to this because of the type of stimuli used. Natural scenes were used in the present study, whereas Parish-Morris et al. presented participants with four separate objects in quadrants of the screen thereby removing any context or extraneous information which would be present in the visual field in the real world. Indeed the present study improves on stimuli used in previous research which has investigated social attention to 'natural' scenes. The majority of eye tracking studies by Freeth et al. presented participants with scenes which contain one person, often sitting in a room and not engaged in any activity, and Hanley et al. (2013) presented participants with images containing close up shots of people with little background information. This is likely to mean that the people in the scenes were salient objects. Increased salience of the people in the scenes, could aid participants with ASD to attend to them to a greater extent. Chevallier et al. (2013) and Freeth et al. (2011) both found typical social attention in ASD when social information was salient. Saliency of the people in scenes in the present studies was not manipulated as a measure of voluntary attention to naturally occurring scenes was being investigated. Therefore it is possible that increasing the saliency of social information in images increases social attention in ASD, but when there are no clues within the image that social information should be attended, adults with ASD do not preferentially attend to it, and show a more exploratory style of visual attention. This interpretation supports the Social Motivation Theory of autism (Chevallier et al., 2012) as it suggests that with no salience guidance, adults with ASD do not choose to attend to people, as appeared to be evidenced in the present experiment. Additionally, the scenes used by Wilson et al. (2010) were artificially manipulated by adding images of people and non-social objects to scenes. The present study utilised scenes which contained naturally occurring social and mechanical objects, and retained some context as the people in the scenes were naturally going about their lives rather than posing for photos. In this way the stimuli were most similar to those of Riby and Hancock (2008) who also used photographs of people in natural scenes which retained context, and the results of the present study are most like those of Riby and Hancock (2008) as they also found that participants with ASD spent overall less time fixating faces than control participants.

The present findings support ideas from the Social Motivation Theory of autism which cites evidence of reduced social orienting in ASD (Chevallier et al., 2012) and the EMB theory which predicts a reduction in social drive in ASD. The ASD group spent less time fixating on the people within scenes in the present study. Previous research has identified a reduction in attention to social information in infants as young as 6 months who later receive a diagnosis of autism relative to infants who develop typically (Jones & Klin, 2013). It is thought that reduced attention to social information from a young age leads to social difficulties downstream as infants do not learn vital social skills such as joint attention and interpreting emotions and social cues (Dawson, Webb, & McPartland, 2005). The present study shows that lower levels of social attention in ASD are evident in adulthood when looking at visual attention allocation to people in natural scenes.

Whilst many studies have found differences in visual attention to faces or eyes in ASD (e.g. Jones et al., 2008), and unusual eye contact forms part of the ADOS (Lord et al., 2000), the present study finds that it is not just faces and eyes that are attended atypically in ASD, but also that people in general are not prioritised in attention in ASD compared to non-social objects. If people with ASD do not prioritise social information in their environment, this would limit their ability to further process social information such as interpreting how another person in their environment is feeling, or in recognising the identity of another person.

Some limitations to the present study should be noted. The sample size of the present study was relatively small owing to difficulties with calibration of the eye tracker and recruiting participants with ASD, which may impact on the generalisability of results, especially given the heterogeneity of ASDs. However, it is within a typical range for published eye tracking studies in ASD research (for example Bird et al., 2011, had 13 participants with ASD and 13 controls; Fletcher-Watson et al., 2009, had 12 ASD participants and 15 control participants; Sasson and Touchstone, 2013, had 15 participants in each group). Additionally, the sample size is above that which was indicated by a priori power analyses (see Chapter 3).

The scenes used in the present study were natural scenes and therefore provided greater ecological validity than stimuli used in other previous research such as object arrays (Sasson et al., 2008) and embedded faces. However, the choice to use natural scenes meant that low level features of the stimuli were not controlled for. Luminance, contrast and colour were not matched in scenes, although it was ensured that no bright colours extraneous to the objects of interest were included in the AOIs which could draw attention beyond the object itself. Therefore it is possible that bottom up stimulus properties resulted in the ASD group allocating a greater proportion of their fixation time to the background rather than the social or mechanical objects. Amso et al. (2014) found that children with ASD directed their gaze according to bottom up properties of the visual stimulus to a greater extent than control participants, regardless of whether social information within scenes was visually salient in the scene, whereas control participants attended more to social information even when it was not visually salient. This therefore raises a potential alternate explanation to diminished social motivation in explaining the results of the present study. The EPF account of ASD (Mottron et al., 2006) may explain why attention was captured by the background of scenes to such a large extent in the ASD group. Enhanced perceptual functioning may have made bottom up influences on visual attention impossible to ignore even though people were visible in the scenes. It would be useful to explore this in future research by comparing fixation patterns of ASD and control participants to saliency maps of the scenes (Itti & Koch, 2000). This potentially suggests that attention atypicalities underlie reduced social attention rather than a reduced social drive per se. A reduction in social drive could be an artifice of increased distraction by extraneous objects in the visual field. The present study cannot determine whether social motivation or enhanced perceptual functioning theories best account for the result of diminished social attention in ASD and increased attention to the background of scenes as the background of the scenes was not manipulated or controlled.

The current results of reduced fixation time to social information is the same pattern that was found in Chapter 6, where higher levels of autism traits were found to relate to lower proportions of fixation time in social areas. This supports the notion of a spectrum of autism traits that extends below the clinical cut off. It suggests that it is not only behavioural traits (as measured by the self-report AQ), but also attentional differences associated with ASD are shown to a lesser extent in those with high levels of autism traits. Chapter 6 found a relationship between autism traits and the broad measure of proportion of total fixation time to social information, but there was no relationship evident in relation to the latency of first fixations to each AOI, suggesting autism traits are not related to prioritising social information within a natural scene. In the present study, there were significant group differences indicating a reduction in attentional preference for social information in the ASD group relative to the control group in each measure of fixation. This shows that the relationship uncovered in relation to autism traits is even stronger when looking at individuals with a diagnosis of an ASD, and suggests that atypical visual attention exhibited by those with a diagnosis of ASD may also lie on a continuum.

In conclusion, the findings of the present study suggest that adults with ASD have reduced attention to social elements of scenes compared to typically developed controls. The participants with ASD did not prioritise social elements of scenes whereas the control group did, evidenced by longer latencies to first fixate the people in the scenes in the ASD group. The ASD group also spent less time fixating on the people in scenes and had shorter fixations in those areas compared to the control group. The ASD group were not found to distinguish between social and mechanical elements of scenes in terms of their allocation of visual attention towards them, suggesting that neither people nor mechanical objects received attentional priority, and the majority of fixation time was spent on the background of the images. This suggests that when attention is completely under the volitional control of the observer, when viewing natural scenes which present social information in a wider context, individuals with ASD do not show an attentional bias for social information that was found in typically developed adults.

Chapter 10
General Discussion

Chapter Abstract: Chapter 10 summarises the experimental findings presented in the current thesis. Results relating to the orienting of attention, the disengaging of attention, and overall looking time to social and non-social objects are then consolidated across experiments, with consideration of the continuum of autism traits. The findings from all six experiments are then considered as a whole. Implications of these findings are discussed, along with limitations of the present research and potential future research directions.

10.1 Thesis Summary

The present thesis aimed to explore visual attention to social and non-social objects across the autism spectrum through examining the orienting and disengaging components of attention, as well as overall looking time towards these objects. Three studies explored these elements of attention in the subclinical spectrum of autism traits, and three in those with a diagnosis of ASD. The present thesis aimed to make several unique contributions to knowledge. First, experimentally controlled methods which had previously not been used in autism research were used to isolate the orienting and disengaging elements of attention to social and non-social objects. These were then augmented by the use of eye tracking technology exploring free viewing of scenes. This enables a comparison across experiments to assess what factors within experiments might account for similarities or differences in attention in ASD. Second, the eye tracking stimuli were created to retain as much ecological validity in exploring attention to people and CI objects, which has been lacking in some past research. Third, research on attention to CIs is a relatively new area and the present thesis contributed to this using tightly controlled experimental methodology not previously used in this area. Finally, the use of exactly the same methodology with a group of participants from the general population with high and low levels of autism traits, and with participants with ASD compared to control participants, enables a comparison of the differences in attention patterns across the clinical threshold. This enables evaluation of the notion of a continuum of autism traits above and below the clinical threshold, and whether attention differences fall on this continuum. Additionally, the comparison of results from subclinical and clinical studies evaluates the utility of research which uses an index of autism traits in the readily accessible general population to assess differences that may be present in the less accessible clinical population of people with ASD.

The key findings from each chapter are first briefly summarised, then results are considered in the domains of orienting attention, disengaging attention, and then overall looking time. The overall picture with regards to social and non-social attention, and the validity of a subclinical autism spectrum are then discussed.

10.1.2 Summary of Results

Chapter 4 used a dot probe task to examine the orienting of attention to faces and cars (as an exemplar of an object of circumscribed interest in ASD). Overall, participants demonstrated a greater attentional bias towards faces than cars (see Figure 10.1; note that AQ groups are not split by sex as in Chapter 4 for ease of illustration across the spectrum). However, males with high and low levels of autism traits were found to differ in their attention bias scores to faces and cars across presentation durations. Males with both high and low levels of autism traits were found to orient attention to faces to a greater degree than cars when stimuli were presented for 200ms. However, when stimuli were presented for 500ms, only the males with high levels of autism traits showed a greater attention bias towards faces than cars whereas the males with low levels of autism traits showed no difference in their attention allocation to faces and cars when stimuli were presented for this duration. Exploring the strength of attention biases, males with high levels of autism traits were found to show an absolute attention bias towards faces at presentation times of 500ms, but not at presentation times of 200ms. The males with low levels of autism traits showed the opposite pattern, with an absolute attention bias to faces at 200ms but not at 500ms. Females with high and low levels of autism traits both demonstrated an absolute face bias at 500ms, but only the females with low levels of autism traits demonstrated an absolute face bias at 200ms. There was no evidence to suggest that subclinical autism traits were related to orienting attention towards cars as a mechanical object and exemplar of objects that may be of circumscribed interest to people with ASD.

Using a peripheral cueing task, Chapter 5 found no difference between high and low autism trait groups in disengaging attention from faces or cars. All participants were found to be slower to disengage attention from faces relative to cars, regardless of whether they reported high or low levels of autism traits (see Figure 10.2).

Chapter 6 used eye tracking to explore the latency to first fixate on social information and mechanical objects in natural scenes in relation to the subclinical spectrum of autism traits. No relationship was found between autism traits and the latency to make first fixations in social or mechanical areas, or to the background of scenes. All participants were faster to first fixate on areas of scenes containing people than areas of scenes containing objects, or the background of the scenes (see Figure 10.3). A trend was found for participants with higher AQ scores to have shorter fixations on social elements of scenes than those with lower AQ scores, suggesting that high levels of autism traits in the general population are related to faster disengagement from faces than low levels (see Figure 10.4). There were no differences in the length of fixation duration across autism trait groups in relation to the mechanical objects in the scenes, or to the background of the scenes. Higher levels of autism traits were related to less time fixating on the social elements of scenes and more time spent fixating on the background of scenes (see Figure 10.5). Participants in the high and low autism trait groups did not differ in the amount of time that was spent fixating on the mechanical objects in the scenes.

Chapter 7 used the same dot probe methodology as Chapter 4 with ASD and control groups. Whilst both groups showed greater orienting of attention to faces than to cars, the ASD group was found to show a reduced attentional bias towards all types of stimuli relative to the control group (see Figure 10.1). The ASD group did not show an absolute attention bias towards any stimuli whereas the control group demonstrated an absolute face bias towards face stimuli at presentation times of both 200ms or 500ms.

Using the same peripheral cueing task as Chapter 5, Chapter 8 found that the ASD group was slower to disengage from face stimuli than car stimuli, whereas the control group showed no difference between the two (see Figure 10.2). This unusual finding was further explored by adding the filler trials, where the cues were images of houses, to the analysis. When combining house and car stimuli as non-social stimuli, it was found that all participants were slower to disengage from faces relative to non-social stimuli. Similarly to Chapter 5, this shows that when attention is forced to engage on faces, disengagement from faces is typical in ASD.

In the eye tracking task in Chapter 9, it was found that participants with ASD were slower to initially fixate on social areas, and faster to fixate on the background of scenes than the control participants (see Figure 10.3). Participants with ASD were equally fast to first fixate in social or mechanical AOIs, and outside either. Additionally, participants with ASD were found to have shorter fixations on the people within natural scenes than control participants (see Figure 10.4). The ASD group did not differ in the length of fixations to any areas of the scenes, whereas the control group had longer fixations within the social AOIs of the scenes than the mechanical AOIs, or the background of the scenes. Participants with ASD also spent less time overall fixating on the social elements of scenes than the control group, and more time fixating outside the social and mechanical areas of the scenes (see Figure 10.5). There were no group differences in the amount of time spent fixating on the mechanical objects in the scenes.

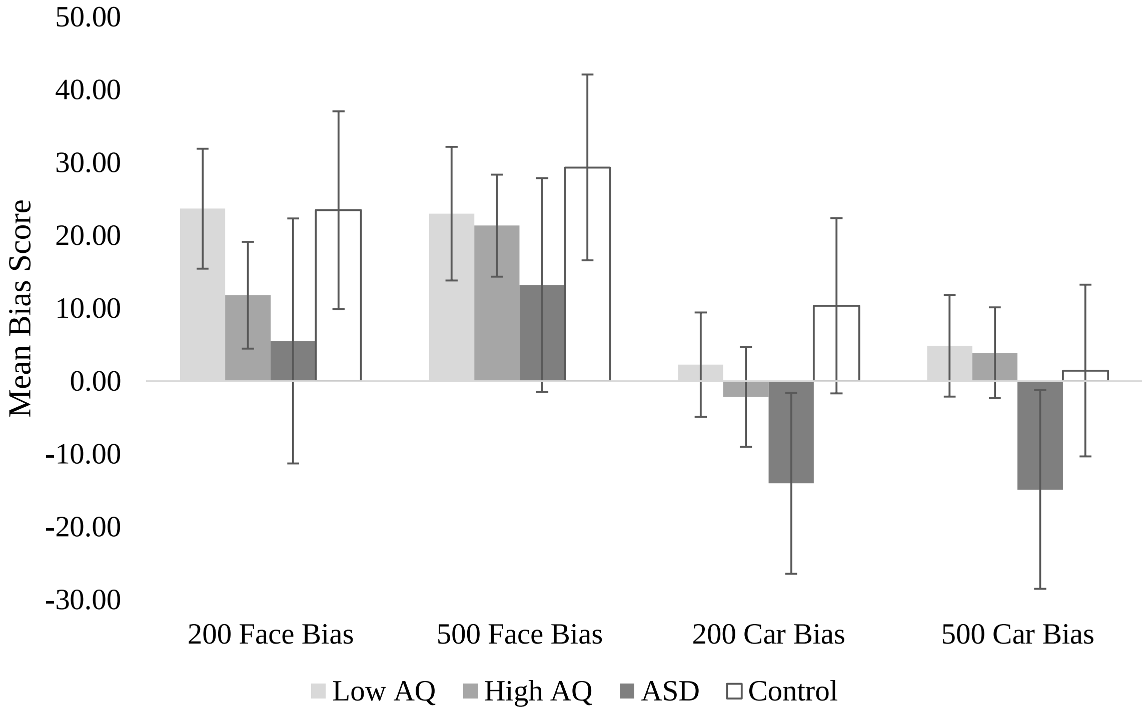


Figure 10.1. Bar chart summarising attention bias score data for groups that participated in the dot probe experiment. NB. Low AQ = low autism trait group from Chapter 4; High AQ = high autism trait group from Chapter 4; Control = control group from Chapter 7; ASD = ASD group from Chapter 7. Error bars show 95% confidence intervals of the means.

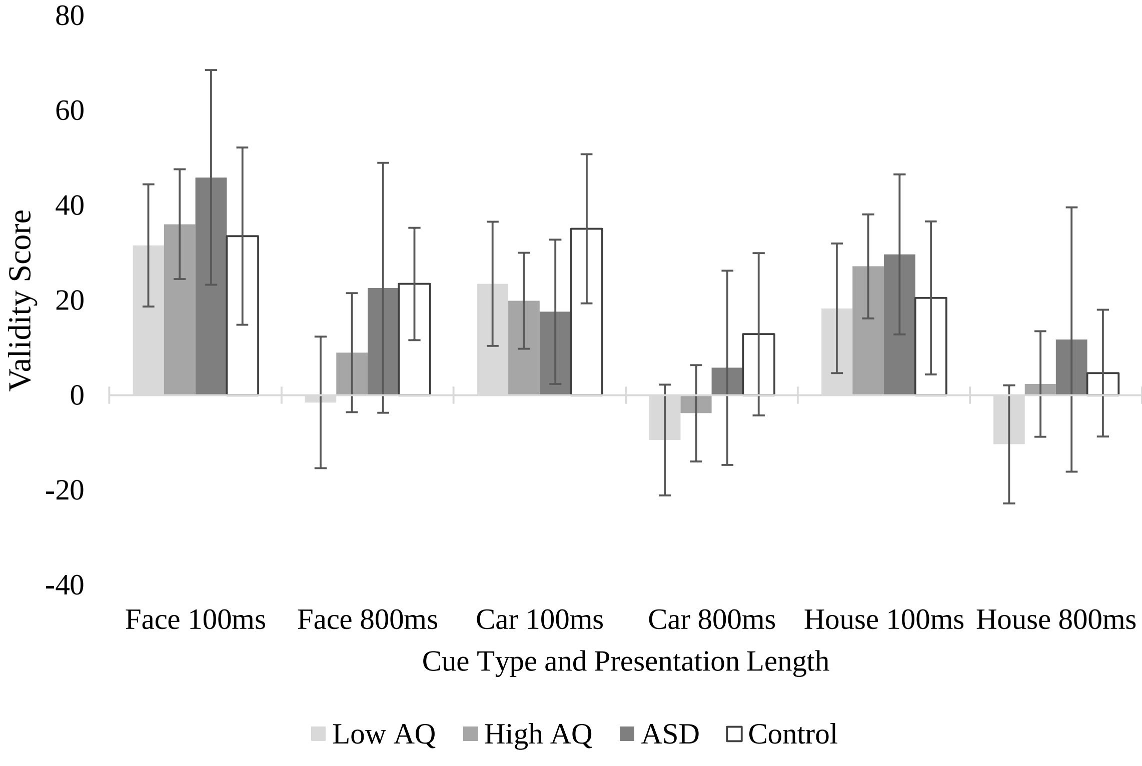


Figure 10.2. Mean validity scores all groups of participants in the peripheral cueing experiment. Error bars show 95% confidence intervals of the mean.

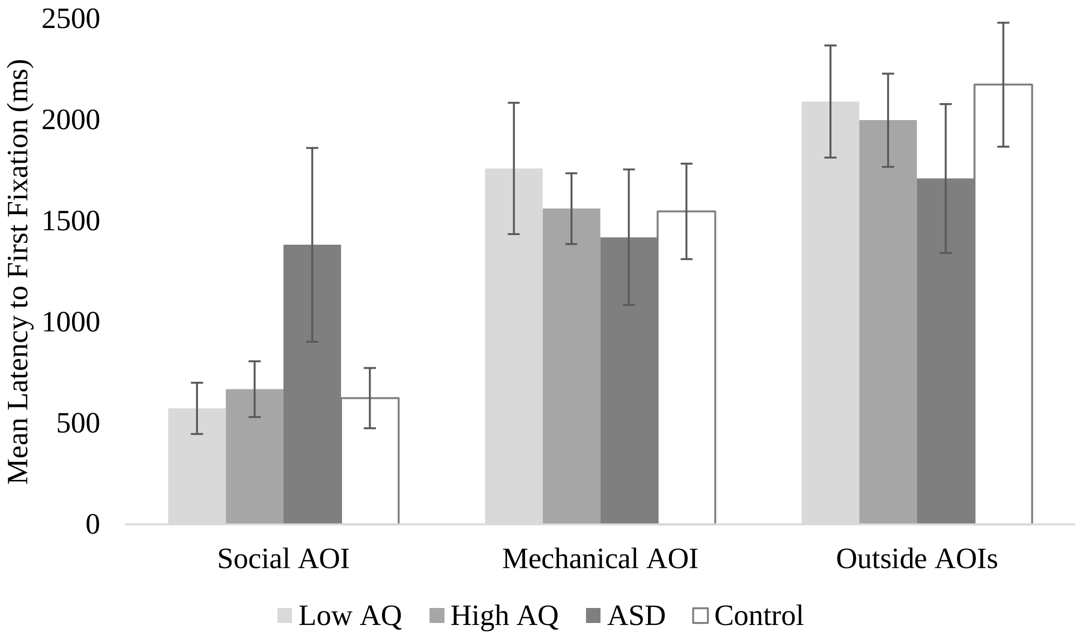


Figure 10.3. Latency to first fixations in Social and Mechanical AOIs, and outside either AOI for all groups who completed the eye tracking task. Error bars show 95% confidence intervals of the mean.

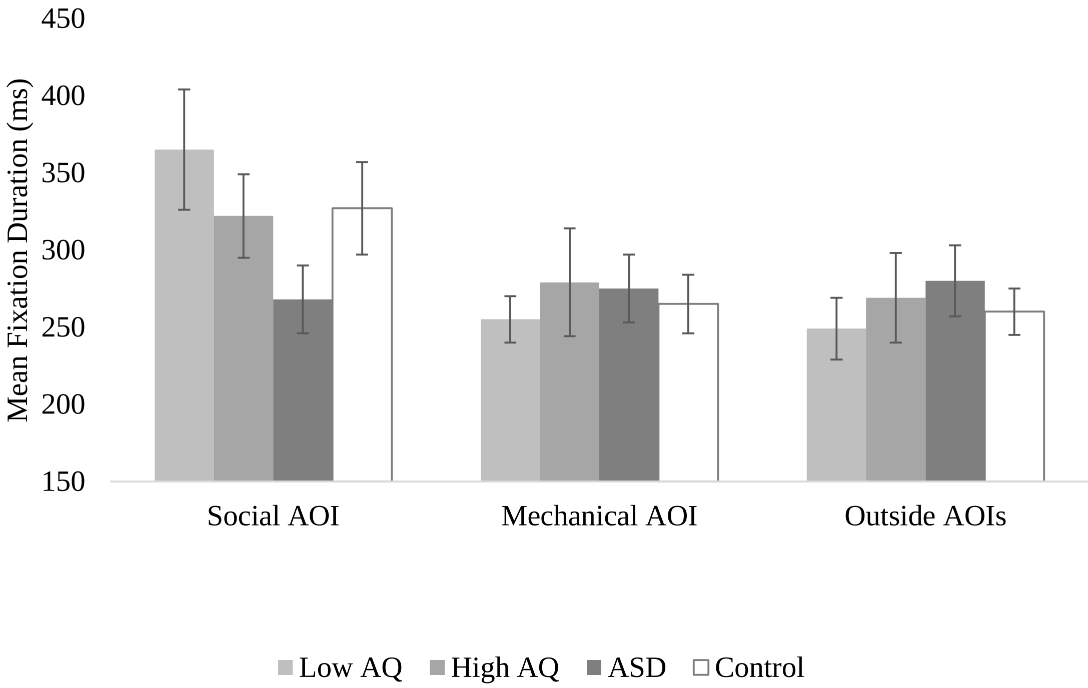


Figure 10.4. Mean fixation durations for all groups in the eye tracking tasks for Social and Mechanical AOIs, and Outside either AOI. Error bars show 95% confidence intervals of the mean.

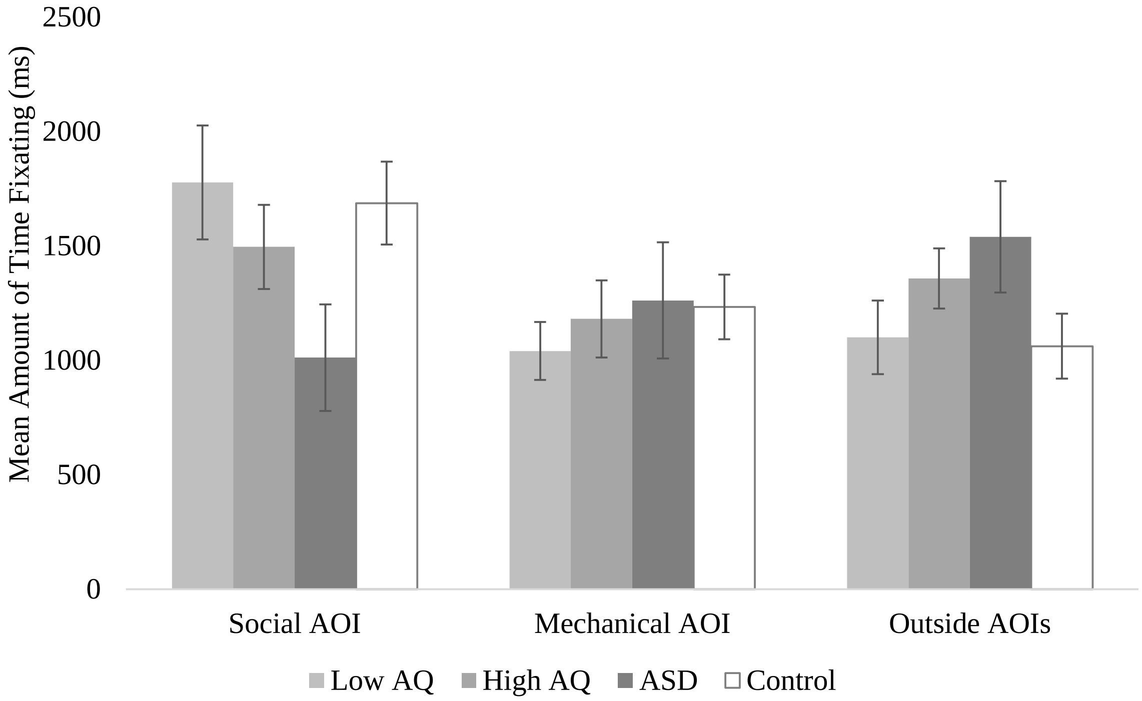


Figure 10.5. Mean time spent fixating within each AOI for all groups in the eye tracking experiments. Error bars show 95% confidence intervals of the mean.

10.2 Orienting attention to social and non-social objects in the Autism Spectrum

Within the two dot probe experiments, there was evidence to show that all participants were faster to orient attention to faces than car stimuli. This is consistent with previous research which has highlighted the special priority that social information receives in the allocation of visual attention (Bindemann et al., 2007; Birmingham & Kingstone, 2009). However, there was also evidence to show that the tendency to orient attention towards social information was not as strong in people with high levels of autism traits and ASD.

The presentation time of 200ms in the dot probe task aimed to capture rapid, automatic orienting of attention towards faces. Both the control group from Chapter 7 and the low autism trait group from Chapter 4 demonstrated an absolute attentional bias towards faces at this presentation time, but the ASD group and high autism trait males did not. The reduced innate orienting of attention to social information is thought to be a contributory factor in the development of social skills in ASD. If individuals with ASD do not prioritise social information in their visual field, then this may have cascading effects in their experience of interpreting social information, and the cortical specialisation for processing faces (Johnson, 2005; Schultz, 2005). The findings from the dot probe experiments support this theory that rapid automatic orienting of attention to faces is disrupted in the autism spectrum. The rapid, selective orienting of attention appears to fall on a continuum along with self-reported autism traits as measured by the AQ. Correlations were performed to explore the relationship between AQ scores and attention biases, combining participants from both dot probe experiments (Table 10.1). Face bias scores at 200ms were found to negatively correlate with total AQ scores (Figure 10.6), showing that higher levels of self-report autism traits are related to reduced automatic orienting of attention towards faces. This evidence of a continuum of social attention atypicalities in relation to autism traits further supports the hypothesis that a reduction in social orienting may contribute to ASD symptomology, although a correlation does not infer causation. This is contrary to the suggestion of Johnson (2014) that innate social orienting is intact in ASD. Johnson's argument is based on the work of Shah et al. (2013) and Jones and Klin (2013), who both found typical social orienting in participants with ASD. However, the results from the dot probe task and Johnson's (2014) argument are not necessarily incompatible. In both dot probe experiments in the present thesis, across all groups, attention biases were found to be greater towards faces than cars. This suggests that there is a tendency to orient towards social information. However, this may be reduced when there are competing images in the visual field. Shah et al. (2013) presented facial configurations with inverted facial configurations in their version of the dot probe task. This simple and meaningless comparison object, which was identical to the facial configuration in terms of low level visual properties, did not attract attention away from the face image. However, in the present thesis, the faces were paired with photographs of houses which were not perfectly matched in terms of low level visual properties to the faces, as would be the case in real world situations. The competition between the two images may have resulted in the reduction in attention biases towards faces in those with ASD and males with high levels of autism traits. This may either be a result of the reduced semantic salience of faces, or the greater competition between low level visual properties of the two images. These two competing theories relating to reduced social attention in the autism spectrum are considered across all experiments later on in the present chapter.

The presentation time of 500ms in the dot probe experiments aimed to capture later, top down attention biases towards faces which are more indicative of motivation to attend to these stimuli. Males with high levels of autism traits were found to demonstrate an absolute attention bias towards faces at this presentation time where they hadn't at 200ms. However, participants with ASD did not demonstrate an attention bias towards faces even when presented for 500ms. This suggests that below the clinical threshold, a reduced orienting drive towards faces may be compensated for by slower top down mechanisms, but this is not the case for those with a diagnosis of ASD. The later attention bias towards faces in males with high levels of autism traits may relate to slower, atypical face processing strategies that have been found to be used by people with ASD and high levels of autism traits (Adolphs et al., 2008; Lahaie et al., 2006). This may indicate that males with high levels of autism traits are slower to recognise the face stimuli as socially salient than males with low levels of autism traits. This top down drive to orient to the face stimuli appeared to be reduced or absent in the participants with ASD who did not show an absolute attention bias to faces at 500ms. However, there was no relationship between AQ scores and attention bias scores to faces at 500ms (Table 10.1) suggesting that levels of autism traits do not impact on the ability to orient attention towards faces when time is allowed for slower, top down processing to take place.

Whilst the dot probe task presents only two competing images and measures experimentally controlled orienting of attention within short time limits, the eye tracking task presented social and mechanical objects in a naturally occurring scene and therefore provides evidence of how attention is rapidly allocated in a more ecologically valid way. Therefore whilst rapid orienting of attention to faces was found to be atypical in males with high levels of autism traits in the experimentally controlled dot probe task, it appears that individuals with high levels of autism traits from the general population are able to compensate for this during free viewing. This could potentially be via top down control rather than rapid automatic orienting, which may be indicative of social motivation. First fixations across all participants and all areas of the scenes mostly occurred later than the 200ms presentation time of the dot probe (mean time after image onset of first fixations in Chapter 6 was 370ms). However, the dot probe task found differences in males but not females in relation to orienting attention to faces and the sample in the eye tracking task were predominantly female. It is possible that with a greater number of males in the sample in Chapter 6, sex differences may have emerged with regards to the latency to fixate people within a scene. Despite the lack of group difference in the latency to first fixate social information in the subclinical autism spectrum, there was a significant positive relationship between AQ scores and the latency to first fixate social information across experiments (Figure 10.6). It appears that this relationship is mostly driven by the ASD group being particularly slow to initially fixate the social areas of scenes. Again, for the ASD and Control groups, first fixations typically occurred later than the rapid automatic orienting of the dot probe task (mean = 383ms for ASD group and 352ms for control group, no significant difference, $t(23) = -0.95$, $p = .35$), and are therefore indicative of top down allocation of visual attention.

Across both the dot probe and eye tracking tasks, the ASD group did not appear to demonstrate an attention orienting bias towards any type of stimuli, with attention being allocated equally across the objects in the visual field. The ASD group were found to show reduced attention biases to all stimuli relative to the control group in the dot probe task, and showed no difference in the latency to first fixate any areas of the visual field in the eye tracking task. This appears indicative that all objects within the visual field were being treated equally in ASD, and this may be the result of a greater influence of bottom up visual information and reduced top down guidance (Amso et al., 2014; Pellicano & Burr, 2012) in where attention is oriented to in ASD. The lack of an attention orienting bias towards any type of stimulus was unique to the ASD group with the high autism trait groups showing an attention bias towards faces when under top down control.

With regards to non-social stimuli, participants were not found to demonstrate an attention orienting bias towards the mechanical objects. However, across experiments, AQ scores were found to correlate negatively with attention biases towards cars at 200ms (Figure 10.7), showing higher levels of autism traits were associated with lower attention biases towards cars. Considering the negative relationship between AQ scores and attention biases to faces at 200ms as well, this supports the notion mentioned above that higher autism traits, and particularly ASDs, are associated with a reduction in attention biases towards any type of stimuli at the point of rapid orienting. This pattern could also be conceived as a greater attention bias towards the house images that were paired with both the faces and cars in the dot probe task as a neutral stimulus. The house stimuli were rated as more complex than the car stimuli, but as equally complex as the face stimuli. If attention is guided by bottom up information in the visual field in those with a greater number of autism traits, it is possible that areas of contrast in the house stimuli were capturing attention and reducing attention biases towards both faces and cars. Additionally, across the eye tracking experiments, the latency to make a first fixation on the background of scenes (outside either social or mechanical areas) was negatively related to AQ scores (Figure 10.7), showing that higher AQ scores were associated with faster first fixations on the background of scenes. Once again this may indicate that areas of bottom up visual salience are capturing attention to a greater degree than social information in those with higher levels of autism traits, as has been found by Amso et al. (2014) in children with ASD. The results regarding the orienting of attention indicate that reduced social orienting may be the result of competing information in the visual field in ASD and high levels of autism traits as opposed to a reduced social drive. Social drive was evidenced to some extent in the dot probe task as, in both dot probe experiments, all participants were found to demonstrate an attentional bias towards faces that was greater than towards cars.

Table 10.1. *Correlations between experimental measures and total AQ scores for all participants in dot probe and eye tracking experiments*.

Measure	Face Bias at 200ms (*n* = 153)	Face Bias at 500ms (*n* = 153)	Car Bias at 200ms (*n* = 153)	Car Bias at 500ms (*n* = 153)	Latency to first fixate social AOIs (*n* = 53)	Latency to first fixate Mechanical AOIs (*n* = 53)	Latency to first fixate outside AOIs (*n* = 53)
r	-.21*	-.10	-.19*	-.12	.57**	-.24	-.27
p	.010	.244	.018	.137	< .001	.087	.052

*p < .05, **p < .001.

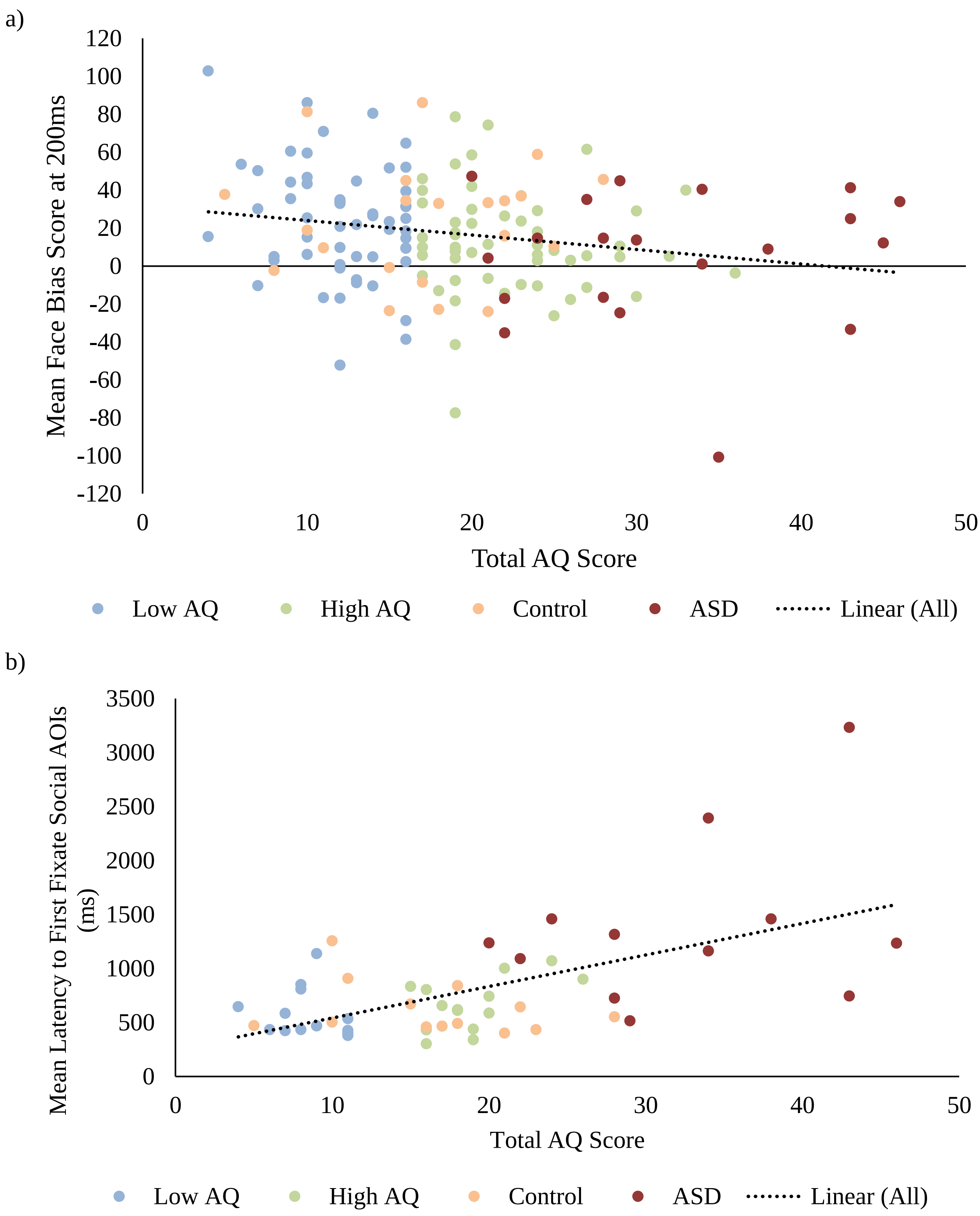


Figure 10.6. Scatterplot showing the relationship between a) total AQ scores and attention bias scores towards faces when stimuli were presented for 200ms in the dot probe task; and b) total AQ scores and latency to make first fixations within social AOIs for all participants in eye tracking tasks.

a)

b)

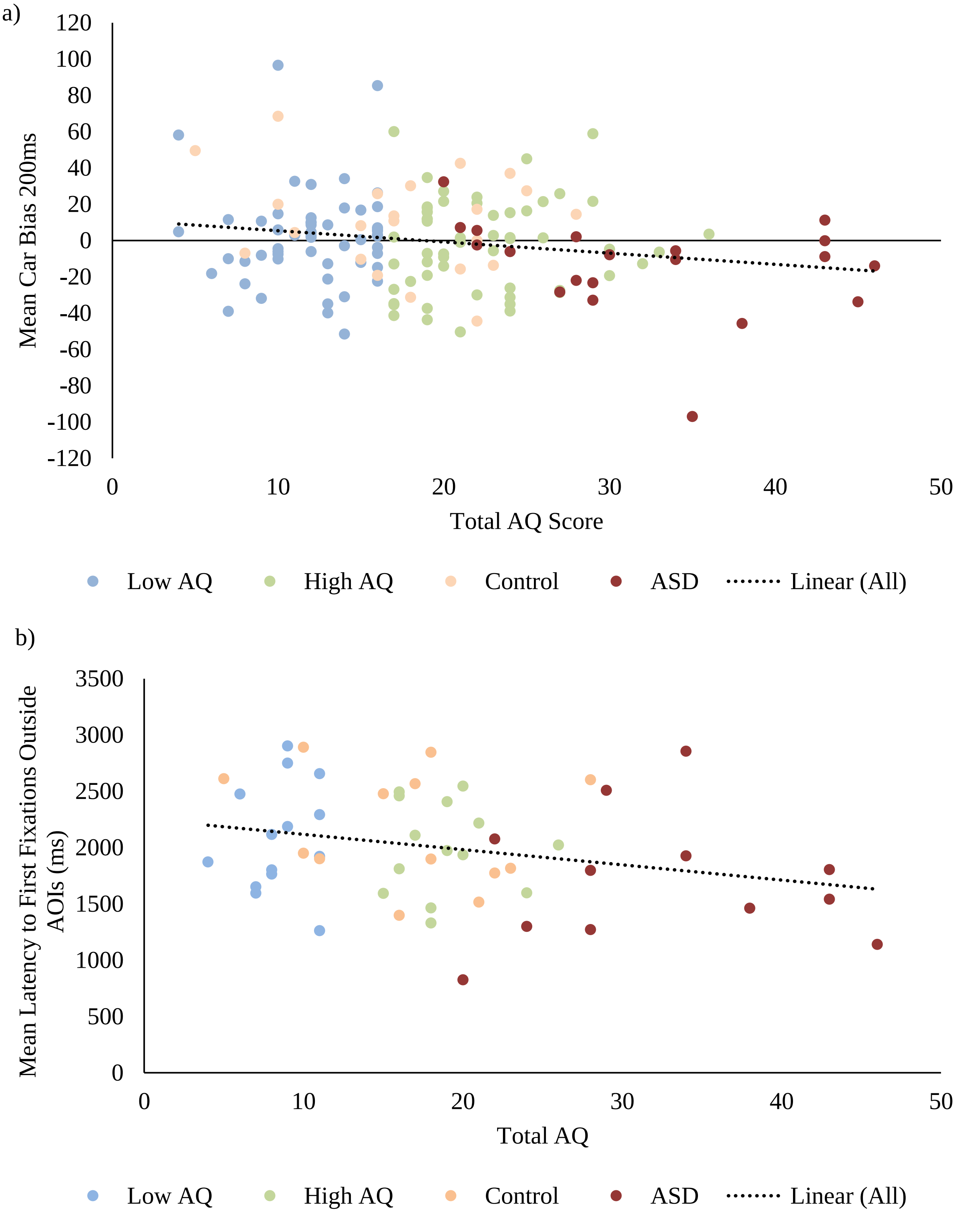


Figure 10.7. Scatter plots showing the relationship between a) AQ scores and attention bias scores for car stimuli presented for 200ms in the dot probe task; and b) total AQ scores and the mean latency to make a fixation outside the social and mechanical AOIs

10.3 Disengaging Attention from Social and Non-Social Objects in the Autism Spectrum

Measuring the disengagement of attention from different categories of stimulus provides an index of an individual's engagement with particular types of stimuli. Slowed disengagement from a particular category of stimuli can be indicative of reward value, long term learned importance, current goals, arousal, familiarity or negativity (Fox et al., 2001; Frewen et al., 2008; Vogt et al., 2008). Both participants with ASD and high levels of subclinical autism traits showed typical slowed disengagement of attention from faces compared to other non-social stimuli in the peripheral cueing task. This suggests no difference in disengaging attention from faces either above or below the clinical threshold of autism traits. However, when viewing people within natural scenes, there was a trend for the people within the scenes to hold attention to a greater degree in those with low levels of autism traits than those with high levels. Participants with ASD also had shorter fixations on social elements of scenes than the control participants. This suggests that during free viewing of natural scenes, participants with higher levels of autism traits are faster to disengage from social information than people with lower levels. There was no suggestion that high levels of autism traits or a diagnosis of ASD was associated with slower disengagement from cars as an exemplar of a mechanical category of circumscribed interests.

In the eye tracking task, the high autism trait group showed a trend towards significance for fixations to be shorter in social areas of scenes than the low autism trait group, and the ASD group had significantly shorter fixations in social areas than the control group. The effect size of the interaction term between group and fixation duration in the areas of scenes was smaller in the subclinical study, $\eta_p^2 = .19$, than in the ASD vs Control study, $\eta_p^2 = .40$. This therefore supports the notion of a spectrum of social attention differences in parallel to a spectrum of autism traits as a bigger effect was found in those with ASD compared to controls than those with high levels of autism traits compared to people with low levels of autism traits from the general population. This spectrum of social attention differences is further supported by correlations between AQ scores and each measure of disengaging attention (see Table 10.2). As would be expected from the findings of Chapters 5 and 8, there was no significant relationship between AQ scores and disengaging attention in the peripheral cueing task. However, AQ scores negatively correlate with the mean duration of fixations on the social areas of scenes in the eye tracking task (see Figure 10.8). This shows that higher levels of autism traits are associated with shorter fixations on people. Longer fixations on people within natural scenes in the participants with lower levels of autism traits was anticipated, and are likely indicative of greater interest in these areas compared to others, or increased familiarity with social information compared to other information (Ro et al., 2007).

Table 10.2. *Correlations between experimental measures of disengaging attention and total AQ scores for all participants in peripheral cueing and eye tracking experiments.*

Measure	Validity Score for faces at 100ms (*n* = 136)	Validity Score for faces at 800ms (*n* = 136)	Validity Score for cars at 100ms (*n* = 136)	Validity Score for cars at 800ms (*n* = 136)	Mean fixation duration in social AOIs (*n* = 53)	Mean fixation duration in Mechanical AOIs (*n* = 53)	Mean fixation duration outside AOIs (*n* = 53)
r	.14	.10	-.07	.06	-.55**	.12	.22
p	.096	.259	.425	.473	< .001	.397	.108

***p* < .001.

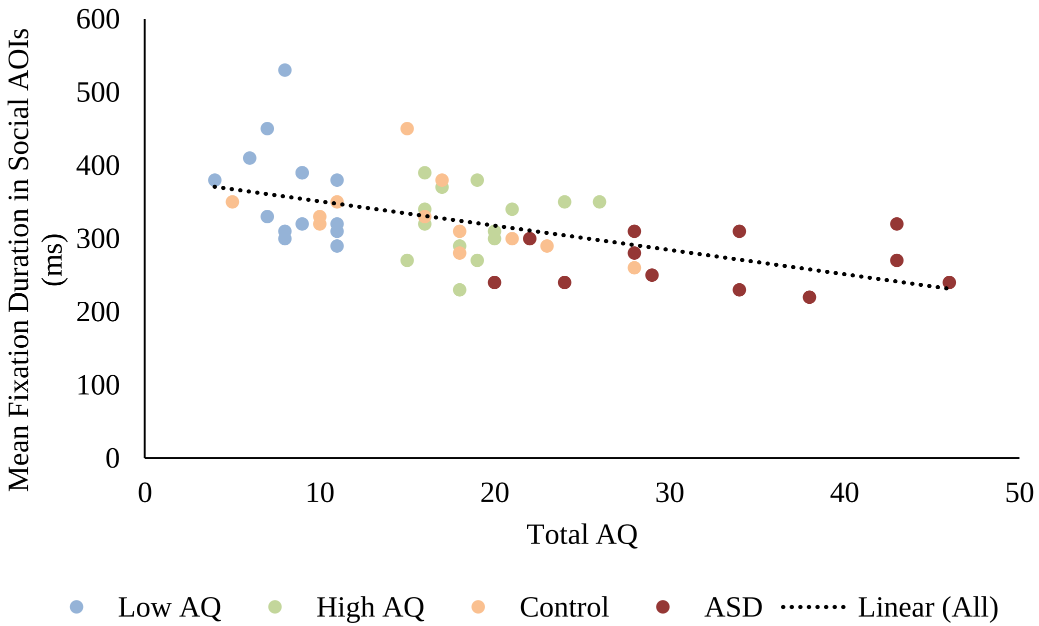


Figure 10.8. Correlation between total AQ scores and the mean duration of fixations within Social AOIs for participants in the eye tracking studies.

The results from the peripheral cueing and eye tracking experiments appear contradictory with disengagement from social information appearing typically delayed in relation to the autism spectrum in the peripheral cueing task, but with no delay in disengaging attention from social information in the eye tracking task, suggesting atypical social disengagement in the autism spectrum. However, the two different methodologies which obtained these results may shed light on why social attention may sometimes appear typical and sometimes atypical in ASD. The peripheral cueing task presented stimuli one at a time, so no other objects in the visual field were competing for attention. In the eye tracking task, however, social and mechanical objects were presented within a naturally occurring scene meaning that there was a lot more visual information competing for attention. This therefore indicates that competing visual information may interfere with social attention in the autism spectrum.

It is possible that people within more complex scenes do not ‘pop out’ as salient to individuals with ASD and high levels of autism traits during free viewing, but when they do attend to faces with no competing stimuli in the visual field, they hold attention to a greater degree than other objects. This indicates that faces may have priority within visual attention compared to other objects when there is nothing else to draw attention in the visual field, and therefore other visual information may detract attention away from social information in more complex scenes such as those presented in the eye tracking study. This is consistent with the findings of Kikuchi et al. (2011) who found that children with ASD did not show slowed disengagement of faces relative to other objects unless they were instructed and prompted to fixate on the eyes of the face. This suggests that under free choice participants with ASD may be engaging attention on less relevant areas of faces or people, and potentially cognitively processing them no differently to other objects. A possible implication of this is that if people with ASD do not maintain information on social information for long periods of time, they may not sufficiently be able to process information from that person such as their identity and emotions. Maintaining attention to social information may aid people with ASD to process information about identity and emotions which is a skill that has been found to be diminished in ASD (Harms, Martin, & Wallace, 2010; Weigelt, Koldewyn, & Kanwisher, 2012), especially if people with ASD tend to use slower, feature based methods of face processing (Hickey et al., 2010; Lahaie et al., 2006).

A social motivation account of ASD does not appear capable of accounting for the pattern of results relating to disengaging attention from social stimuli in both the peripheral cueing task and the eye tracking task. Lower reward value of social information for participants with higher levels of autism traits could explain the shorter fixations on people within scenes in the higher end of the autism spectrum relative to the lower end. However, it does not account for why the same participants who completed the eye tracking task were also slower to disengage attention from faces relative to non-social stimuli in the peripheral cueing task. The peripheral cueing task appears to indicate that faces do have a priority in attention allocation in those with high levels of autism traits. An alternative account, as was offered in Chapter 8, could argue that the nature of the peripheral cueing task, where attention is covertly forced to the face stimuli, lead to increased arousal in those with ASD (Dalton et al., 2005) and therefore delayed disengagement from face stimuli. However, again this potential interpretation does not account for why this would not have been the case in the eye tracking experiment, as the very fact that a fixation has occurred on a person within a scene indicates that social information is being attended to. In the eye tracking studies, however, fixations in social AOIs did not necessarily have to fall on the face of the person in the scene as bodies were included within the AOIs. This could have meant that fixations within social AOIs were not leading to increased arousal in those with high levels of autism traits and ASD and therefore were not causing slowed disengagement. When the findings related to disengaging attention are considered alongside those relating to the orienting of attention and overall looking time, an explanation suggesting the increased salience of non-social information, possibly as a result of bottom up influences on visual attention emerges as the most likely. This is discussed in section 10.5 below.

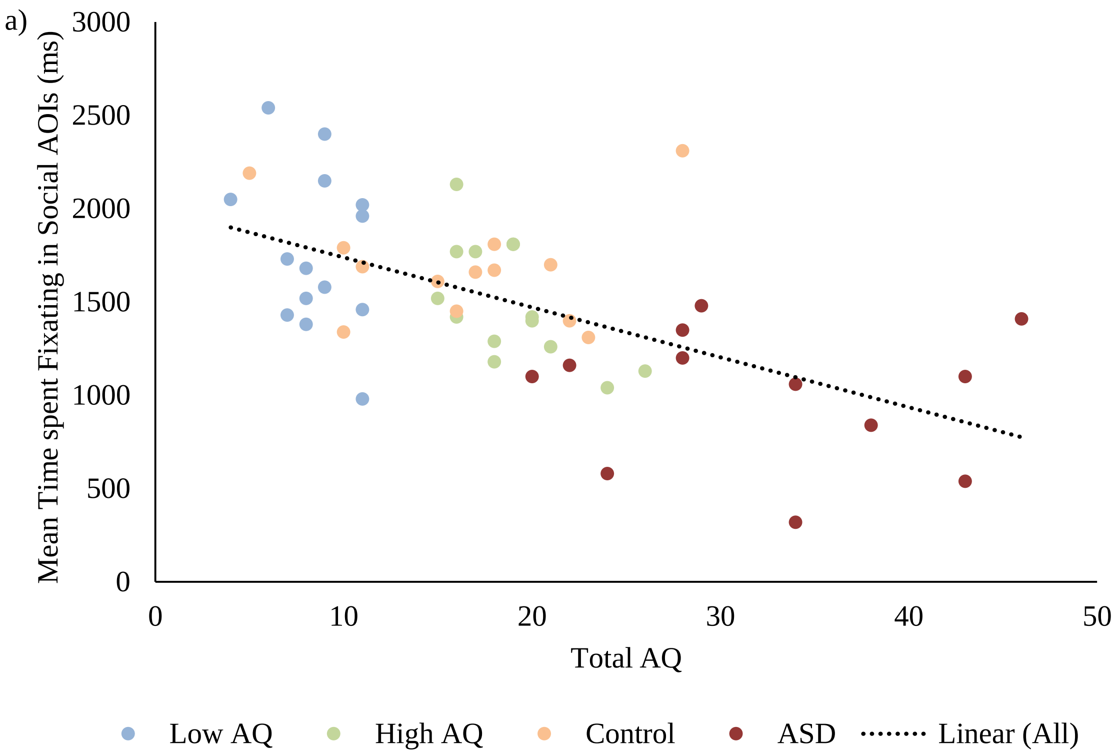
10.4 Overall looking time to Social and Non-Social objects During Free Viewing

The overall looking time to social and mechanical areas of static natural scenes was explored using eye tracking to give an indication of which types of object participants volitionally allocate their attention to. The same pattern of differences was found between the low and high autism trait groups as between the ASD and control groups, with the high autism trait group and the ASD group spending less time fixating social areas of scenes and more time fixating the background of scenes than their comparison groups. The results from these two experiments support the notion of a spectrum of attention to social and non-social information from individuals from the general population through to people with a diagnosis of ASD. The effect size of the interaction between overall time spent fixating in each AOI and group was larger in the ASD study (η_p^2 = .427) than in the study relating to levels of subclinical autism traits (η_p^2 = .154). This suggests that social attention and autism trait severity are related, with social attention atypicalities being more pronounced in those with ASD relative to people from the general population with high levels of autism traits. Correlations between total AQ scores and the amount of time spent fixating the different areas of the scenes across both eye tracking studies further support this (see Table 10.3). A strong negative correlation was found between AQ scores and the amount of time fixating on the people within the scenes across experiments (see Figure 10.9), showing that higher AQ scores were associated with less time spent fixating on social information. A moderate positive correlation between AQ scores and the time spent fixating on areas other than the social and mechanical objects within scenes was also found (Figure 10.9) showing that greater levels of autism traits were associated with more time spent fixating on the background of the scenes. There was no relationship between AQ scores and the amount of time spent fixating on the mechanical objects in the scenes. This supports the notion that atypicalities in social attention are also present in those with subthreshold levels of autism traits, but to a lesser extent than those with a diagnosis of ASD, and indicates that attending to social information relates to the level of severity of autism traits. Whilst correlation cannot establish causation, this may highlight a useful area for intervention. It is possible that increasing social attention in people with ASD may improve social abilities such as joint attention and emotion recognition, as suggested by Fletcher-Watson (2014).

Table 10.3. *Correlations between total AQ scores and the amount of time spent fixating within Social and Mechanical AOIs, and outside either AOI, for all participants in eye tracking experiments.*

Measure	Mean time fixating in social AOIs (n = 53)	Mean time fixating in Mechanical AOIs (n = 53)	Mean time fixating outside AOIs (n = 53)
r	-.60**	.20	.32*
p	< .001	.146	.020

*p < .05, **p < .001.



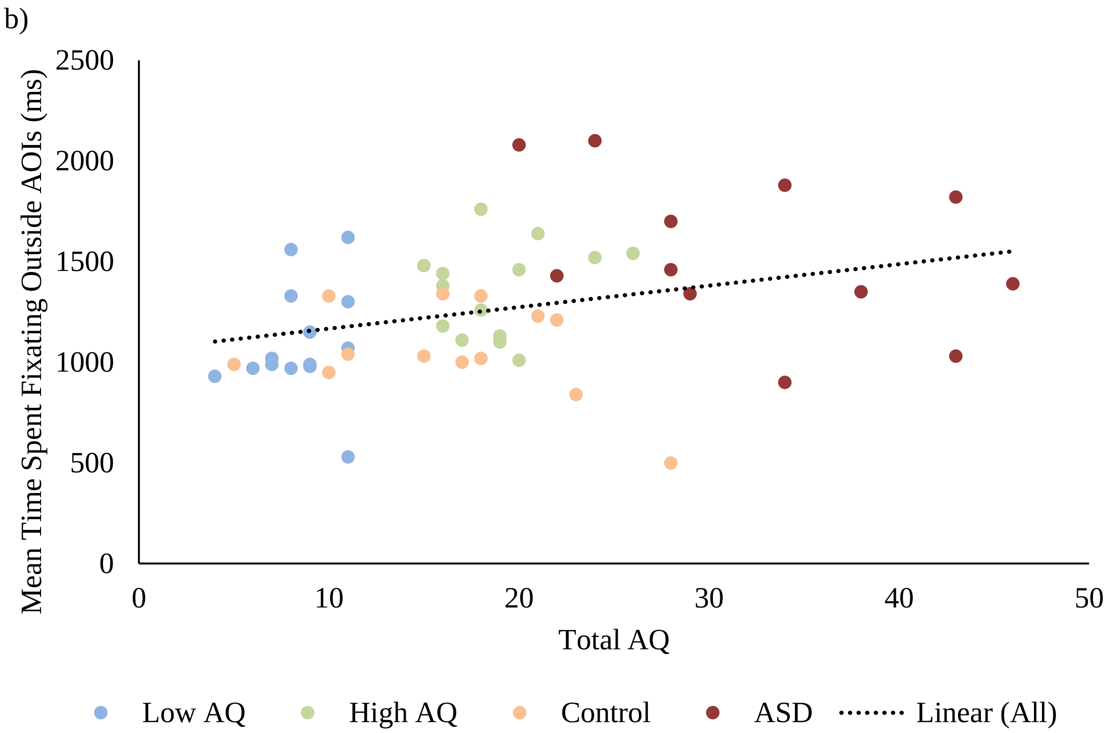


Figure 10.9. Correlation between AQ scores and the mean amount of time spent fixating a) within Social AOIs, and b) outside social and mechanical AOIs for all participants in eye tracking studies.

The eye tracking measure of overall looking time to social and mechanical areas of natural scenes improved upon previous research by including these elements within real scenes from everyday life as opposed to in object arrays (Sasson et al., 2008), or with one person shown sitting in a room (Freeth et al., 2010). The images were similar in their realistic nature to those of Riby and Hancock (2008), but extended these by also including mechanical objects to relate to circumscribed interests. The results described above relating to a decrease in overall looking time to people within scenes is in contrast to other studies which have found that participants with ASD spend as much time as typically developing controls fixating the people within scenes (Fletcher-Watson et al., 2009; Freeth et al., 2010). However, the results are in support of other research which has found differences in overall looking time to people within natural scenes in ASD (Riby & Hancock, 2008). The stimuli used in the present study were most similar to those of Riby and Hancock in that they were photographs of complex scenes that were naturally occurring, were not posed, as in Freeth's work, and the people within the scenes were engaged in activities rather than simply sitting at a desk (as in Freeth's work). Therefore this suggests that differences in social attention across the autism spectrum are strongest in studies which retain as much ecological validity as possible.

The mechanical elements within scenes were more varied in the eye tracking task compared to the dot probe and peripheral cueing tasks within the present thesis, yet even so, there was no difference across low and high autism trait groups, and ASD and control groups in the amount of time spent fixating on these objects. Sasson and Touchstone (2013) found that children with ASD looked less at faces when they were presented with images of objects relating to CIs, and the CI objects used by Sasson and Touchstone were similar to those used in the present study (including trains, planes and vehicles). It is possible that attention towards these particular categories of CI is increased in children with ASD, but not adults. However, CIs have been found to persist into adulthood (Mercier et al., 2000), and one study identified that the most common focuses of CI do not alter from childhood to adulthood (Anthony et al., 2013). Additionally, the ASD sample for the eye tracking study comprised of 38% females, which is a larger proportion of females to that typically observed in individuals with ASD (Ehlers & Gillberg, 1993). Anthony et al. (2013) found that the primary interests in their sample of 109 people with ASD were different between males and females. The most widely reported intense interests in males with ASD across ages 7-22 were video games, Lego, and playing games alone, whereas for females they were numbers and maths, music, or others (not specified). Therefore this suggests that the mechanical items in the eye tracking task may not have encapsulated an area of CI for the female participants with ASD. Further research would benefit from exploring attention towards objects of CI specifically for females with ASD, and by identifying common areas of circumscribed interests in adults with ASD, to build on the findings of South et al. (2005) and Turner-Brown et al. (2011) who explored the content of CIs in relation to children with ASD.

The measure of the total amount of time spent fixating within or outside of the social and mechanical areas in the eye tracking studies provides insight into where participants freely allocate their attention over a five second period. Previous research has shown that during eye tracking, properties of the visual stimulus guide attention to a greater degree than top down processes when viewing natural scenes (Parkhurst, Law, & Niebur, 2002). However, when there are people present within the scenes, it has been found that they attract attention beyond visually salient elements of the scenes (Birmingham et al., 2009; Freeth et al., 2011). Birmingham et al. (2009) suggest that the bias to attend to social information within scenes is driven by an interest in social information. It is possible that attention to the people within scenes was diminished in the present thesis as a result of lower social motivation in those with ASD and subclinical autism traits (Baron-Cohen, 2002; Chevallier et al., 2012). Looking at the people within scenes could have been more rewarding for the participants with lower levels of autism traits resulting in increased fixation time on those areas of scenes. This is consistent with accounts of autism that suggest that social deficits are primary to the disorder. However, it was anticipated that the mechanical objects as a category of circumscribed interests in ASD may be of more reward value and capture attention to a greater extent, but there was no relationship between the autism spectrum and overall looking time to the mechanical objects. Alternatively, in accordance with the EPF theory of autism (Mottron et al., 2006), the people amongst the competing objects within the scenes may not have been salient enough to capture attention for individuals with ASD and high levels of autism traits due to the high level of visual input. This would suggest that differences in social attention are the result of general perceptual differences in ASD, rather than social motivation deficits. The relative abilities of these theories to account for the present findings are discussed in the wider context of the thesis as a whole below.

In summary, it appears that high levels of autism traits in the general population and ASD are associated with a reduction in attention to social information and an increase in attention to other, non-social information. This may be because attention is more guided via bottom up processes rather than recognising the people within scenes as salient objects. This could be the result of a reduced interest in social information, and simply seeing people as no different to any inanimate object, or it could be because bottom up influences on visual attention in ASD are so strong that they override the innate drive to look at people.

10.5 Overall Interpretation of Findings

The results highlighted above indicate differences in attention to social information in relation to the autism spectrum in all areas of visual attention that were measured. Where differences were found between the high and low autism trait groups, larger differences were found between the ASD and control groups. Therefore this suggests that social attention atypicalities are continuously distributed and related to the continuum of autism traits. However, there were some variables where a difference was found in the ASD group but not the high autism trait group, as in the latency to first fixate social areas in the eye tracking tasks. However, this may relate to the largely female sample in Chapter 6, and therefore research investigating attention differences in subclinical autism traits may benefit from using mostly male samples in order to uncover differences which may not be present in females with high levels of autism traits. Additionally, the pattern of findings across experiments appears to indicate that as more objects compete for visual attention, social attention diminishes in those with ASD and high levels of autism traits.

The disengaging element of attention to social and non-social objects was found to be typical in relation to the autism spectrum in the peripheral cueing task, with participants with high autism traits and ASD being slower to disengage attention from faces than other non-social stimuli. However in the dot probe and eye tracking tasks, orienting, disengaging, and overall looking time to social and non-social objects was found to be atypical in relation to the autism spectrum. These findings might suggest that the difference in ASD is based on competing visual properties within a scene. When attention was forced to a face via exogenous cueing with no other competing stimuli in the peripheral cueing task, people with ASD and high levels of autism traits were slower to disengage from faces than other objects, as were the participants with low levels of autism traits and control participants. This suggests therefore that faces were salient to this group once they had engaged attention on them, as they were forced to do by the peripheral cueing task. Furthermore, Remington, Swettenham, and Lavie (2012) found that under conditions of high perceptual load, people with ASD were still distracted by task irrelevant (non-social) distractors. The authors suggest that ASD is associated with greater perceptual capacity as high perceptual load did not exhaust their processing capacity. This would mean that in the complex eye tracking scenes, participants with higher levels of autism traits were more distracted by background objects within scenes as their perceptual load was not exhausted, whereas participants with low levels of autism traits were able to focus attention on the areas of the scene that were most semantically salient to them, such as the people within scenes. However, this does not seem to apply to faces. Remington, Campbell, and Swettenham (2012) found that when perceptual load was high, participants with ASD were able to ignore task irrelevant face images whereas control participants were not. In the latter experiment, the distraction from the face images resulted from determining their gender as the task involved judging whether a name was male or female. The distraction in the former study came from shapes that were physically similar to the target. Therefore visual properties may have a greater influence on the distractibility of individuals with ASD. This suggests that as displays became more complex in the present thesis, from one stimulus presented in isolation in the peripheral cueing task, to two in the dot probe, to a full natural scene in the eye tracking task, attention may have been allocated based more on the perceptual properties of the images in the ASD and high autism trait group than on processing the gestalt of the images. In several variables, the ASD group did not differ in attention between social, mechanical, or other objects. This therefore implies that social information is not as salient to people with high levels of autism traits or ASD when competing with other information. However, when presented in isolation, the face stimuli held attention to a greater extent than other non-social stimuli in all participants.

The findings of the present thesis are compatible with the Social Motivation theory of ASD (Chevallier et al., 2012) and the EMB theory of ASD (Baron-Cohen, 2002) both of which predict a reduced social drive in relation to ASD. However, the findings regarding mechanical objects do not support the systemising drive that people with ASD are found to have. The present findings, however, do not rule this possibility out as the stimuli may not have sufficiently encapsulated objects related to systemising that are of CI to people with ASD. The Social Motivation theory suggests that individuals with ASD may show an attentional preference for general non-social information rather than non-social objects relating to CIs specifically (Chevallier et al., 2012), and therefore the Social Motivation theory may better account for the pattern of results across the present thesis than the EMB. The Social Motivation theory specifically focuses on the social deficits in ASD, as Happé and Ronald (2008) argue is a useful approach to take when considering cognitive accounts of ASD. However, when considering why attention to non-social stimuli in the autism spectrum is atypical, the findings may also relate to the WCC (Happé & Frith, 2006) and EPF (Mottron et al., 2006) accounts of ASD. The WCC account of ASD could account for social and non-social attention atypicalities being the result of attending to images as parts, rather than considering the gestalt of a stimulus or scene, thereby allocating information to parts rather than considering objects in the visual field as meaningful wholes. Additionally, in accordance with the EPF theory of ASD, more visually salient elements of the visual scene may capture attention via bottom up influences to such a high degree that individuals with ASD cannot ignore them, despite social information being present and an intact social drive. The pattern of results in this thesis, described above, in relation to the number of competing images in the visual field appears to suggest that social attention is typical when no other objects are competing for attention, but that it becomes increasingly atypical the more objects are in the visual field. This therefore suggests that a social motivation theory alone may not be able to account for the social attention differences in ASD, and that cognitive theories of ASD may be overlooking important influences on social behaviour if they do not take into account factors other than social drive. It could be the case that reduced social motivation is a downstream effect of other information in the visual field being more salient to those with ASD rather than a primary deficit in the reward value of social information.

The present thesis found no evidence to suggest that social attention atypicalities in relation to the autism spectrum are the result of heightened social anxiety which has been found to relate to subclinical autism traits and to be more prevalent in individuals with ASD than the general population (Freeth, Bullock, & Milne, 2012; White et al., 2012; White et al., 2011). This may simply be because no social stimuli typically used to relate to threat (e.g. angry faces) were used in the present thesis. The neutral faces in the dot probe and peripheral cueing tasks and people in the eye tracking task may not have been emotive enough to be perceived as threatening in those with high levels of subclinical social anxiety. Alternatively, as has been found by Hollocks et al. (2013), individuals with ASD and high levels of social anxiety may not display typical attention biases towards threatening information. This requires further investigation as the present thesis did not specifically aim to explore the relationship between social anxiety, autism traits and social attention, and the threat content of the social stimuli was not manipulated. Social anxiety was measured only to establish whether differences in social attention were influenced by social anxiety rather than autism specifically, as two studies have reported attention differences to neutral faces compared to non-social objects in relation to social anxiety (Chen et al., 2002; Garner et al., 2006).

If people with high levels of autism traits and ASD are spending less time looking at people within their visual environment and instead look more at other areas of the visual field than people without ASD with low levels of autism traits, then this is likely to impact on their ability to engage with people in the real world. It is possible that the profile of overall looking time seen in the present thesis across the autism spectrum may manifest in behaviours associated with ASD such as greater distractibility when engaged in social interaction, or a failure to notice that someone they know is nearby (Tomchek & Dunn, 2007; Weigelt et al., 2012). This could then contribute to social communication difficulties that are characteristic of ASD such as “failure of normal back-and-forth conversation” due to distraction from other elements in the visual field capturing attention, or “failure to initiate… social interactions” as a result of not being aware that a person they know is nearby (p.50, American Psychiatric Association, 2013). Further, it may inform social attention based interventions by highlighting the need to increase attention to social information when it is embedded in more complex visual scenes, rather than simply supporting a skill such as facial recognition by showing one face on a screen (e.g. as in Rice, Wall, Fogel, & Shic, 2015).

No differences were found in attention towards mechanical objects in any of the measures of attention across participants with ASD or differing levels of autism traits. This suggests that, contrary to predictions, these objects do not automatically or voluntarily capture attention in participants with high levels of autism traits or people with ASD. It was thought that these objects might have greater reward value, or be related to areas of expertise as mechanical objects are related to domains in which people with ASD are often identified as having circumscribed interests (Baron-Cohen & Wheelwright, 1999; South et al., 2005; Turner-Brown et al., 2011). Previous research has found that children with ASD attend less to faces when faces are paired with objects relating to CIs (trains, planes, vehicles, clocks and blocks), but not when the faces are paired with other objects that did not relate to CIs (Sasson & Touchstone, 2013; Sasson et al., 2008). In the present thesis, attention to mechanical objects, as an exemplar of CIs, was tested compared to another non-social object in the dot probe task, in isolation in the peripheral cueing task, and in the same scene as social objects in the eye tracking task. Mechanical objects were not found to capture attention differently to other non-social objects in any tasks. In the eye tracking task, where Sasson et al. (2008, 2013) found that attention to social information diminished in the presence of CI objects for children with ASD, the present study found reduced social attention in adults with ASD and high levels of autism traits, but not because participants were attending more to the mechanical objects in scenes. There were no group differences in attention to mechanical objects in the eye tracking task. Instead it appeared to be the other non-social areas of the scenes that were attracting attention more in the eye tracking task, and the dot probe task suggested that the houses were capturing attention to a greater degree than cars for the ASD group.

If adults with ASD and high levels of autism traits are attending less towards social information in their environment, this may contribute to difficulties in social interaction as they may fail to recognise a person, or to interpret non-verbal social cues. Research has previously suggested that social orienting and visual attention to people in scenes is diminished in children with ASD (Bedford et al., 2014; Dawson et al., 2004), and some argue this contributes to the development of ASD (Schultz, 2005). The present findings show that social attention continues to be atypical into adulthood implying that despite greater social experience in adults than in children, this has not led to an increase in attending to social information.

10.6 Implications

The present thesis found that attentional differences to social and non-social objects in ASD were also present to a lesser extent in those with high levels of autism traits. This has wide reaching implications for autism research, as well as for individuals with high levels of subclinical autism traits. In terms of autism research, this adds to the confidence of researchers to be able to extrapolate findings from those with high levels of autism traits to those with a diagnosis of ASD, as it would be expected that if a difference in attention is found relating to subclinical autism traits, it can be expected to be found to a greater degree in people with a diagnosis of ASD. Experimental testing situations can be challenging for people with ASD as they often involve sustained attention and remaining completely sedentary for potentially long periods of time, which may be difficult if a person with ASD has tics or ritualised behaviours they feel compelled to regularly perform. Recruitment of participants with ASD can also be difficult for researchers, whereas there is usually a ready pool of undergraduate students available for research at most academic institutions. Whilst research utilising an ASD sample is ideally preferential to the utilisation of subclinical samples if a researcher is exploring a difference in relation to ASD, there is a growing trend in the literature to conduct research with people with subclinical autism traits and to extrapolate to ASD. The present thesis confirms that this is acceptable, however, there may also be differences in visual attention that are specifically unique to those with autism traits above the clinical threshold. For example, the house stimuli appeared to particularly attract the attention of participants with ASD but this was not seen in those with high levels of autism traits.

Additionally, research illuminating the continuum from subclinical levels of autism traits to clinical levels of autism traits may raise public awareness of this continuum and potentially benefit those who have social difficulties related to autism traits but do not meet diagnostic criteria for ASD. There has been a discourse around subclinical depression and anxiety for many years (King & Buchwald, 1982; Preisig, Merikangas, & Angst, 2001) and symptoms of other psychiatric disorders such as bipolar and psychosis are now considered to fall on a spectrum (Hanssen, Krabbendam, Vollema, Delespaul, & Van Os, 2006; Kwapil et al., 2011). This concept could be argued to trivialise the very real challenges that arise from a psychiatric disorder, however, it also has many potential benefits if the information is used in the right way. It is, of course, important to stress that neither the AQ nor measures of social attention constitute a clinical diagnosis. Subclinical levels of symptoms associated with ASD may themselves lead to significant impairment in quality of life for people in the general population. However, people from the general population with subclinical autism traits are found to have higher levels of social anxiety (Freeth et al., 2012; White et al., 2011) and report greater loneliness (Jobe & Williams White, 2007; Lamport & Zlomke, 2014) than people with lower levels of autism traits. An awareness of subclinical autism traits among the general population may encourage the development and use of self-help materials (for example the self-help guide for adults with Asperger's by Edmonds & Worton, 2005) for people experiencing impairment that does not reach threshold criteria for ASD but is negatively impacting on their life. Additionally, people with milder, subthreshold symptoms of ASD may be directed towards self-help materials by their GP, as is often the case with anxiety and depression, rather than referring them for diagnosis and increasing the burden on services which are vital for those who experience more impairment.

More specifically, the findings of reduced social attention in relation to ASD, especially when viewing natural scenes, have implications for potential interventions to aid social functioning in people with ASD. As the social attention impairments are milder in those with subthreshold autism traits, interventions to increase social attention could potentially lead to an improvement in symptomology. It was found in the present thesis that attention to faces was typical when presented in isolation. Therefore interventions which train adults with ASD to attend to people within more complex visual displays could enhance their ability to automatically attend more to social information in their daily lives, in a similar way to cognitive bias modification in anxiety (e.g. MacLeod & Mathews, 2012).

10.7 Limitations

A number of methodological limitations within the present thesis are acknowledged. With regards to the use of stimuli in the dot probe and peripheral cueing tasks, the houses appeared to capture attention atypically in participants with ASD, drawing more attention than the car stimuli. It is suggested that this is because of the visual properties of these stimuli, as houses were rated more complex by an independent group of participants than the car stimuli. Therefore the car stimuli may have been too visually simple to compete for attention with the more complex house stimuli. However, there was no difference in the complexity ratings between the face and car stimuli which were the stimuli of experimental interest that were being directly compared. The house and car stimuli were selected specifically for their configural similarity to faces. Further research may benefit from utilising other non-social comparison stimuli, perhaps in addition to configurally similar house images, to compare with attention towards faces and CI objects in ASD.

It is possible that the stimuli that were selected as exemplars of CI objects in ASD were not representative of interests of the participants in the present thesis. There were no group differences in how mechanical objects, as a category of objects of circumscribed interest, captured or held attention in relation to the subclinical or clinical spectrum of autism. It is argued that this avenue is still one worth pursuing in future research. Whilst the decision to base stimuli on previous research which had investigated the content of circumscribed interests in persons with ASD was valid, it may not be the best way to explore attention to objects that may be of greater reward value to people with ASD than social information. Circumscribed interests in ASD can be idiosyncratic in nature (e.g. lawn sprinklers, South, 2005; the number 22, Turner-Brown et al., 2011; ukuleles, Klin et al. 2007) and as such, it would be of great benefit to specifically tailor stimuli to individuals personal interests, as has been done by Singleton et al. (2014). Alternatively participants could be asked to rate their interest in the stimulus categories to establish whether this impacts on visual attention or whether it differs in relation to the autism spectrum.

With regards to participants, whilst every effort was made to ensure that diagnoses of participants with ASD were verified via inspection of diagnostic reports and participants' completion of the AQ, it was not possible to administer the ADOS or ADI. As well as being the 'gold standard' in research (Jones & Lord, 2013), these would also have provided useful indexes by which to compare the attention measures in the participants with ASD. Future research would benefit from using these measures to verify diagnoses. Additionally, it would be informative to compare attention measures to the social and restricted and repetitive domains of the ADOS (Lord et al., 2000), for example.

Additionally, it is acknowledged that the sample of participants with ASD represented the high functioning end of the clinical spectrum and sample sizes were small, particularly in the eye tracking study. This may impact on the generalisability of results, especially given the heterogeneity within people with a diagnosis of ASD (Geschwind & Levitt, 2007). However, the sample sizes met the criteria for a priori power analyses and effect sizes were found to be medium to large indicating that despite the small sample sizes, a meaningful difference between groups was found. Furthermore, as was addressed at the beginning of the thesis, results from those with higher functioning ASD are likely to generalise to those with more severe autism (Fletcher-Watson et al., 2009).

Finally, the present thesis rests on the assumption that the AQ accurately measures and represents the autism spectrum. The AQ is a well validated measure of autism traits in both the general population and amongst persons with ASD (Baron-Cohen, Wheelwright, Skinner, et al., 2001; Hoekstra et al., 2008; Woodbury-Smith et al., 2005), however it has been met with some criticism. Kanne et al. (2012) developed the SATQ to improve upon the AQ by extending the range of behaviours measured to include an ‘oddness’ subscale in order to better capture autism traits as opposed to just Asperger’s traits, which the authors claim the AQ covers. Initial comparisons suggest the SATQ may be superior to the AQ in terms of internal consistency (Nishiyama et al., 2013). If further validation of this new measure supports its superiority to the AQ, then this may be a useful measure to include in future research which requires a measure of subclinical autism traits in order to further replicate and test the consistency of findings in the present thesis with other indexes of autism traits.

10.8 Future research directions

The present thesis shows that social attention is reduced in relation to subclinical autism traits and clinical ASD, and suggests that this may be the result of increased attention to other non-social areas of the visual environment. The research presented in the thesis does not answer the question as to whether this is the result of general attention differences or because of a reduction in social interest. Future research would benefit by exploring the relationship between social motivation, motivation towards objects of circumscribed interest, and visual properties of stimuli, thereby encompassing the Social Motivation, EMB, WCC and EPF theories of autism. The findings of diminished social attention in relation to autism traits across the clinical and subclinical spectrum, and increased attention to the ‘other’ category of non-social objects suggests that attention is driven more by the visual properties of stimuli than their meaning in ASD.

It is often documented that individuals with ASD have a particular interest in cartoons (Grelotti et al., 2005), or show typical face processing styles to cartoon faces but not photographs of faces (Brosnan, Johnson, Grawmeyer, Chapman, & Benton, 2015; Rosset et al., 2007). It could be that this is due to the simplicity, and sharp contrast gradient of cartoons, with each object having a distinct outline. This sharp contrast gradient would mean that cartoon images are more visually salient via bottom up information than photos where contrast gradients are less steep. Additionally, individuals with ASD have been found to perform better on tasks detecting simple contrast sensitivity changes than more complex ones (Bertone et al., 2005). It is possible that more complex stimuli, such as photographs of real faces compared to cartoon or schematic faces, may be aversive to individuals with ASD (Mottron et al., 2006), which may contribute to diminished social attention. Completing the dot probe task with face and circumscribed object stimuli consisting of either full colour photos, detailed line drawings, or simple cartoons would determine to what object attention is preferentially allocated in ASD and under what conditions. The Social Motivation theory of ASD suggests that individuals with ASD experience a diminished reward response to social information, which leads to a decrease in attending to social information and atypical social behaviours (Chevallier et al., 2012). The reward value of social and non-social stimuli relating to circumscribed interests could be manipulated in relation to stimuli of differing complexity as described above. Behavioural training could teach participants to associate different types of pictures with different types of reward (social, CI related or other non-social). This should also be explored in participants with ASD and participants with differing levels of subclinical autism traits to establish whether any of the factors of stimulus type, reward type, or level of complexity differentially impact on visual attention above and below the clinical threshold. The manipulation of these three variables may also inform interventions to improve social attention in individuals with ASD, based on the theory that enhanced social attention leads to greater cortical expertise and social processing skills (Johnson, 2005).

10.9 Thesis Conclusions

To conclude, the six experiments presented throughout this thesis have shown that the selective rapid orienting of attention towards faces is diminished in males with high levels of autism traits, and individuals with a diagnosis of ASD. The differences in orienting attention to social information appear to follow a spectrum from subclinical to clinical, with those with ASD orienting the least to faces, followed by those with high levels of autism traits, then those with low levels. In a peripheral cueing task, disengaging attention from faces relative to other non-social objects was found to be slowed across the whole autism spectrum. It is suggested that when social information is presented in isolation, this may facilitate social attention in relation to the autism spectrum. Indeed, the present thesis showed that the more competing objects there are in the visual field, the less attention is allocated to social information in those with high levels of autism traits and ASD. Social attention differences in relation to the autism spectrum were most pronounced during the free viewing of naturalistic scenes containing social and mechanical elements. There was no evidence to suggest that mechanical objects, as exemplars of objects of circumscribed interest in ASD, captured attention atypically in relation to the autism spectrum. It is argued that this is reflective of the choice of stimuli and not necessarily conclusive evidence that such attentional atypicalities do not exist. This highlights the need for future research to consider a more individualised approach when exploring visual attention towards objects of circumscribed interests. An unexpected finding of the present thesis appears to indicate that the autism spectrum, above and below the clinical threshold, was associated with an increase in attention to 'other' non-social areas of the visual field. A suggested interpretation of this is that properties of objects in the visual field may receive greater priority in the allocation of attention in ASD beyond the semantic salience of objects. Future research is suggested to investigate the impact that visual complexity and motivation may have on attention to social and non-social objects, including objects of circumscribed interest.

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Appendix I

Effect Sizes for Power Analyses

Garner et al. (2006) used a similar methodology to the dot probe task by comparing visual attention biases to faces and non-social stimuli presented in pairs. This study measured attention biases in relation to subclinical anxiety and therefore it is not necessarily directly comparable to subclinical autism traits, and so provides a guide of effect sizes that can be achieved with this type of methodology. The reported effect size for differences between high and low anxiety groups across attention biases to social and non-social stimuli is large, d = .81. However, given the different dimension explored (subclinical anxiety as opposed to sub clinical autism traits), a more conservative medium effect size was estimated. Additionally, a measure of orienting to social information can be taken from Fletcher-Watson et al. (2009) as they compared first fixations on a person present or person absent scene between ASD and control participants. Using the formula for partial eta squared in Lakens (2013), it was found that this interaction produced a medium effect size, η_p^2 = 0.18. This supports the use of a medium effect size to compute sample sizes for the dot probe tasks.

For the peripheral cueing task, the most methodologically similar study identified was that of Fox et al. (2001), experiment two. This compared disengagement from angry, happy and neutral faces in relation to subclinical anxiety groups. The significant interaction of the highest order reported by Fox et al. produced a medium effect size, η_p^2 = .09.

For the eye tracking studies, it was computed that Riby and Hancock (2008), in an eye tracking study of visual attention to people in natural scenes, found a large effect size for the interaction between group (ASD vs chronological age matched control vs non-verbal age matched control) and area of the scene (face, body or background), η_p^2 = .22.

Appendix II

Raw Reaction Times and Supplementary Analyses for Chapter 4

Reaction Times

Raw reaction time data for the dot probe task in Chapter 4 are presented below for males (Table AII.1) and females (Table AII.2) with low and high AQ scores. These were used to compute the bias scores for the main analysis in Chapter 4.

Table AII.1. *Mean (SD) raw reaction times (ms) for males with high and low AQ scores.*

	Low AQ (*n* = 24)		High AQ (*n* = 28)	
Type of Stimulus	Congruent	Incongruent	Congruent	Incongruent
200ms Face	558.25 (86.66)	581.85 (84.20)	549.28 (73.66)	560.82 (72.69)
200ms Car	582.13 (87.68)	579.22 (84.01)	563.06 (74.88)	561.96 (70.92)
500ms Face	550.29 (78.75)	566.19 (88.78)	533.69 (67.62)	533.31 (75.68)
500ms Car	562.79 (81.41)	566.19 (81.78)	553.31 (74.20)	552.74 (71.14)

N.B. ‘Congruent’ indicates that the target appeared in the location of the stimulus named in the left hand column, ‘incongruent’ indicates that the target appeared in the opposite location.

Table AII.2. *Mean (SD) raw reaction times (ms) for females with high and low AQ scores.*

	Low AQ (*n* = 31)		High AQ (*n* = 28)	
Type of Stimulus	Congruent	Incongruent	Congruent	Incongruent
200ms Face	592.53 (66.68)	616.30 (72.11)	579.52 (71.87)	591.61 (67.37)
200ms Car	616.90 (72.56)	623.22 (80.80)	594.37 (68.68)	591.18 (71.50)
500ms Face	584.08 (69.84)	612.60 (65.69)	571.68 (70.06)	590.60 (74.91)
500ms Car	607.10 (73.43)	607.46 (72.82)	589.63 (71.69)	598.05 (72.78)

N.B. ‘Congruent’ indicates that the target appeared in the location of the stimulus named in the left hand column, ‘incongruent’ indicates that the target appeared in the opposite location.

ANOVA with outlying data points removed

Two participants with Z scores greater than 3.29 for Car Bias Scores at 200ms were removed from the data set and the main Group x Gender x Stimulus x Time ANOVA was repeated. There was a main effect of stimulus, $F(1, 105) = 49.86$, $p < .001$, $\eta_p^2 = .322$, and the Group x Gender x Stimulus x Time interaction was significant, $F(1, 105) = 6.43$, $p = .013$, $\eta_p^2 = .058$.

Breaking this down into a three way interaction within males and females separately, in males there remains a main effect of Stimulus, $F(1, 49) = 28.05$, $p < .001$, $\eta_p^2 = .364$, and a significant interaction between Stimulus, Time and Group, $F(1, 49) = 7.67$, $p = .008$, $\eta_p^2 = .135$. No other main effects or interactions were significant for the males. For females, there was a significant main effect of Stimulus only, $F(1, 56) = 23.67$, $p < .001$, $\eta_p^2 = .297$.

Breaking the three way interaction down across Time in males, at 200ms there was a significant main effect of Stimulus, $F(1, 49) = 21.11$, $p < .001$, $\eta_p^2 = .301$, and the Group x Stimulus interaction approached significance $F(1, 49) = 3.80$, $p = .057$, $\eta_p^2 = .072$. To explore this trend, independent samples t-tests revealed no significant difference between Low and High AQ groups on Face Bias Scores at 200ms, $t(49) = 1.84$, $p = .072$, or Car Bias Scores at 200ms, $t(49) = -0.89$, $p = .381$. Paired samples t-tests found that for the Low AQ group, there was a significant difference between Face and Car Bias scores at 200ms, $t(22) = 4.44$, $p < .001$. For the High AQ Group, there was no significant difference between Face and Car Bias Scores at 200ms, $t(27) = 1.96$, $p = .061$.

At 500ms, there was a significant main effect of Stimulus, $F(1, 49) = 8.34$, $p = .006$, $\eta_p^2 = .145$, and the Group x Stimulus interaction approached significance, $F(1, 49) = 3.96$, $p = .052$, $\eta_p^2 = .075$. To explore this trend, independent samples t-tests revealed no significant difference between Low and High AQ groups on Face Bias Scores at 500ms, $t(49) = -0.95$, $p = .348$, or Car Bias Scores at 500ms, $t(49) = 1.83$, $p = .073$. Paired samples t-tests showed there was no significant difference between Face and Car Bias Scores for males with low AQ scores when presented for 500ms, $t(22) = 0.58$, $p = .571$. For high AQ males, Face Bias Scores were significantly greater than Car Bias Scores at 500ms, $t(27) = 3.80$, $p = .001$.

These results support what was found in the main ANOVA reported in Chapter 4 with a trend for high AQ males to show a delay in orienting towards faces as low AQ males showed a greater face bias relative to cars at 200ms but not at 500ms, whereas high AQ males showed no difference between face and car bias scores at 200ms, but they had greater bias scores to faces at 500ms.

Appendix III

Raw Reaction Times and Supplementary Analyses for Chapter 5

Raw Reaction Times

The raw reaction time data for males and females with high and low AQ scores in the peripheral cueing task in Chapter 5 is shown in Tables AIII.1 and AIII.2. This data was used to compute the validity scores used in the main analysis in Chapter 5.

Table AIII.1. *Mean (SD) raw reaction times (ms) for males with high and low AQ scores.*

	Low AQ (n = 20)		High AQ (n = 27)	
Type of Stimulus	Valid	Invalid	Valid	Invalid
100ms Face	501.09 (60.09)	544.97 (87.23)	532.12 (68.42)	573.23 (75.38)
100ms Car	510.77 (58.71)	545.66 (93.88)	545.60 (72.85)	562.74 (79.03)
100ms House	519.51 (65.03)	548.49 (85.01)	544.18 (67.70)	578.80 (83.51)
800ms Face	503.08 (75.92)	511.48 (62.98)	521.81 (76.03)	537.48 (67.15)
800ms Car	514.93 (74.78)	515.20 (71.87)	537.30 (67.31)	541.38 (72.72)
800ms House	510.45 (69.42)	502.50 (61.58)	533.55 (69.43)	544.21 (77.33)

N.B. ‘Valid’ indicates trials where the target appeared at the same location as the cue, and ‘invalid’ indicates trials where the target appeared at the opposite location to the cue.

Table AIII.2. *Mean (SD) raw reaction times (ms) for females with high and low AQ scores.*

	Low AQ (n = 25)		High AQ (n = 22)	
Type of Stimulus	Valid	Invalid	Valid	Invalid
100ms Face	568.21 (64.73)	589.91 (65.71)	542.74 (48.14)	572.51 (78.90)
100ms Car	573.67 (62.16)	588.05 (77.11)	546.42 (45.03)	569.73 (59.44)
100ms House	580.37 (65.69)	590.11 (75.72)	544.63 (47.58)	562.60 (66.60)
800ms Face	570.02 (72.45)	560.54 (73.53)	539.47 (60.17)	540.15 (43.18)
800ms Car	582.56 (79.63)	565.30 (69.32)	549.98 (56.98)	536.52 (48.63)
800ms House	576.32 (73.43)	564.06 (69.97)	544.66 (59.16)	536.81 (44.66)

N.B. ‘Valid’ indicates trials where the target appeared at the same location as the cue, and ‘invalid’ indicates trials where the target appeared at the opposite location to the cue.

Main ANOVA with outlying data point removed

The participant's data with the outlying validity score for face cues at 100ms was removed from the data set and the main analysis was run again to establish whether the outlier was influential.

Validity scores based on response latencies were the main dependent variable for the study. A Group (Low AQ vs High AQ) x Sex (male vs female) x Cue Type (Face vs Car) x Time (100ms vs 800ms) ANOVA was performed on Validity Sores. A significant main effect of Cue Type was revealed, $F(1, 89) = 18.56$, $p < .001$, $\eta_p^2 = .173$, with Validity Scores being greater for face stimuli (mean = 18.70) than for cars (mean = 7.29). There was also a main effect of Time, $F(1, 89) = 35.36$, $p < .001$, $\eta_p^2 = .284$, with Validity Scores being greater when stimuli were presented for 100ms (mean = 26.94) than 800ms (mean = -0.95). There was a further main effect of Sex, $F(1, 89) = 5.91$, $p = .017$, $\eta_p^2 = .062$, with Validity Scores being greater for males (mean = 19.79) than females (mean = 6.21). The main effect of Group was not significant, $F(1, 89) = 0.41$, $p = .523$, $\eta_p^2 = .005$. Crucially for the present study, there was no significant interaction between Group and any other variables (Cue x Group interaction: $F(1, 89) = 0.99$, $p = .324$, $\eta_p^2 = .011$; Cue x Time x Group: $F(1, 89) = 0.01$, $p = .907$, $\eta_p^2 < .001$; Cue x Group x Sex: $F(1, 89) = 0.23$, $p = .637$, $\eta_p^2 = .003$; Cue x Time x Group x Sex: $F(1, 89) = 0.52$, $p = .473$, $\eta_p^2 = .006$). No interactions between other variables were significant.

Appendix IV
Supplementary Analyses for Chapter 6

ANOVA for Latency to First Fixations with Log Transformation

A repeated measures ANOVA with factors of AOI (Social, Mechanical or outside either) and Group (high or low AQ) performed on the log transformed latency to first fixation data revealed a significant main effect of AOI, $F(2, 52) = 155.07$, $p < .001$, $\eta_p^2 = .856$. Paired samples t-tests revealed that participants were faster to first fixate in Social AOIs than Mechanical AOIs, $t(27) = -11.84$, $p < .001$, or Outside either AOI, $t(27) = -14.59$, $p < .001$. Participants were also faster to first fixate within Mechanical AOIs than outside either AOI, $t(27) = -4.44$, $p < .001$.

The main effect of group, $F(1, 26) = 0.01$, $p = .939$, $\eta_p^2 < .001$, and the interaction between Group and AOI, $F(2, 52) = 1.35$, $p = .268$, $\eta_p^2 = .049$, were not significant.

ANOVA for Mean Fixation Duration with Log Transformation

A repeated measures ANOVA with factors of AOI (Social, Mechanical or outside) and Group (low AQ or high AQ) was performed on the log transformed mean duration of fixations data. There was a significant main effect of AOI, $F(2, 52) = 37.37$, $p < .001$, $\eta_p^2 = .590$. Paired samples t-tests revealed that participants' fixations were significantly longer with Social AOIs than Mechanical, $t(27) = 6.02$, $p < .001$, and outside the AOIs, $t(27) = 7.04$, $p < .001$. There was no significant difference in the mean duration of fixations within Mechanical AOIs our outside either AOI, $t(27) = 0.87$, $p = .391$. There was no significant main effect of Group, $F(1, 26) = 0.03$, $p = .865$, $\eta_p^2 = .001$. The interaction between AOI and Group was significant, $F(2, 52) = 4.81$, $p = .012$, $\eta_p^2 = .156$.

Independent samples t-tests showed a non-significant trend for participants in the Low AQ group to have longer fixations within Social AOIs than the high AQ group, $t(26) = 1.96$, $p = .061$. There was no significant difference between groups in the length of fixations in Mechanical AOIs, $t(26) = -1.08$, $p = .289$, or outside the AOIs, $t(25) = -1.23$, $p = .231$. Paired samples t-tests within each group revealed that fixations were longer in social AOIs than mechanical AOIs for both the Low AQ group, $t(13) = 6.85$, $p < .001$, and the High AQ group, $t(13) = 2.73$, $p = .017$. Additionally, fixations were longer in the Social AOIs than outside either AOI for both the low AQ group, $t(13) = 7.15$, $p < .001$, and the high AQ group, $t(13) = 3.77$, $p = .002$. There was no significant difference between the length of fixations within Mechanical AOIs or outside either AOI for either the low AQ group, $t(13) = 0.83$, $p = .423$, or the high AQ group, $t(13) = 0.48$, $p = .638$.

Appendix V

Raw Reaction Times and Supplementary Analyses for Chapter 7

Raw Reaction Time Data

The raw reaction time data used to calculate the attention bias scores for the dot probe task is presented in Table AV.1 below.

Table AV.1. *Mean (SD) raw reaction times (ms) for ASD and Control Participants.*

	Control Group (n = 22)		ASD Group (n = 20)	
Type of Stimulus	Congruent	Incongruent	Congruent	Incongruent
200ms Face	586.94 (133.69)	610.46 (126.90)	601.31 (108.07)	606.85 (87.72)
200ms Car	601.28 (129.04)	611.64 (137.97)	611.68 (100.28)	597.67 (85.67)
500ms Face	567.90 (124.95)	597.25 (132.78)	580.32 (95.69)	593.53 (86.43)
500ms Car	592.78 (129.59)	594.25 (125.42)	603.76 (107.19)	588.90 (90.35)

N.B. 'Congruent' indicates that the target appeared in the location of the stimulus named in the right hand column, 'incongruent' indicates that the target appeared in the opposite location.

ANOVA with outlying data excluded

A Group (ASD v control) x Bias (face v car) x Time (200ms v 500ms) ANOVA was performed with Attention Bias Score as the dependent variable, and revealed a main effect of Bias, $F(1, 39) = 27.23$, p <.001, η_p^2 = 411, with Face Bias scores (M = 19.16) being greater than Car Bias scores (M = -2.65) for all participants. There was also a main effect of Group, $F(1, 39)$ = 8.79, p = .005, η_p^2 = .184, with Bias scores being greater for controls (M = 16.17) than for ASD participants (M = 0.34). Importantly, the Group x Bias interaction was not significant, $F(1, 39)$ = 0.10, p = .758, η_p^2 = .002, nor was the Group x Bias x Time interaction, $F(1, 39)$ = 0.43, p = .517, η_p^2 = .011. No other main effects or interactions approached significance (all F's < 1.60, all p's > .20).

Appendix VI
Raw Reaction Times for Chapter 8

Raw Reaction Times

The raw reaction times for the peripheral cueing task for participants in the ASD and Control Groups are presented in Table AVI.1 below.

Table AVI.1. *Mean (SD) raw reaction times (ms) for ASD and Control Participants*

	Control Group (*n* = 22)		ASD Group (*n* = 20)	
Type of Stimulus	Valid	Invalid	Valid	Invalid
100ms Face	526.45 (69.07)	560.00 (73.71)	549.50 (107.57)	595.38 (123.11)
100ms Car	530.83 (70.17)	565.89 (85.32)	563.55 (121.11)	581.12 (116.64)
100ms House	539.04 (76.85)	559.53 (82.30)	564.60 (117.17)	594.25 (138.18)
800ms Face	512.32 (68.06)	535.79 (73.20)	550.41 (142.44)	573.03 (140.39)
800ms Car	523.74 (74.79)	536.60 (76.48)	552.04 (130.72)	557.83 (123.22)
800ms House	522.63 (75.34)	527.28 (73.75)	553.87 (137.86)	565.59 (116.23)

N.B. 'Valid' indicates trials where the target appeared at the same location as the cue, and 'invalid' indicates trials where the target appeared at the opposite location to the cue.

Appendix VII

Supplementary Analyses for Chapter 9

ANOVA with log transformed data on mean latencies to first fixations in each AOI

A Group (ASD or Control) x AOI (Social, Mechanical or Outside) ANOVA was performed on the log transformed latency to first fixate data. There was a main effect of AOI, $F(2, 46) = 31.31$, $p < .001$, $\eta_p^2 = .58$. Overall log transformed scores for latency to first fixate Social AOIs were found to be lower than Mechanical, $t(24) = -3.75$, $p = .001$, and Outside either AOI, $t(24) = -5.65$, $p < .001$, and lower within the Mechanical AOI than Outside either AOI, $t(24) = -3.18$, $p = .004$. There was no significant main effect of Group, $F(1, 23) = 1.95$, $p = .176$, $\eta_p^2 = .08$, but the interaction between Group and AOI was significant, $F(2, 46) = 14.72$, $p < .001$, $\eta_p^2 = .39$. Exploring this interaction, independent samples t-tests revealed that the log transformed latency to first fixate Social AOIs was significantly lower for Control participants than the ASD group, $t(23) = -4.35$, $p < .001$. There was no significant difference between groups in log transformed time taken to first fixate within Mechanical AOIs, $t(23) = 0.87$, $p = .393$. The ASD group were found to be faster to fixate outside either AOI than the control group, $t(23) = 2.25$, $p = .034$.

Paired samples t-tests revealed that the ASD group did not differ in the log transformed latency to make a first fixation within Social AOIs compared to Mechanical AOIs, $t(11) = -0.39$, $p = .702$, or compared to outside either AOI, $t(11) = -1.48$, $p = .167$, or between the log transformation of latency to make a first fixation in Mechanical AOIs and Outside either AOI, $t(11) = -1.30$, $p = .222$. However, the Control group's log transformed latency to first fixate within Social AOIs was significantly lower than mechanical AOIs, $t(12) = -8.701$, $p < .001$, and than outside either AOI, $t(12) = -15.47$, $p < .001$. Additionally, the Control participants' log transformed latencies to fixate within mechanical AOIs were significantly smaller than outside either AOI, $t(12) = -3.79$, $p = .003$.

These findings are the same as those presented in Chapter 9 with the untransformed data.

Non-Parametric tests for mean fixation duration

Mann Whitney U tests were used to compare mean fixation durations across the ASD and Control groups. The Control group was found to have significantly longer fixations within the Social AOIs than the ASD group, $U = 18$, $Z = -3.13$, $p = .001$. There was no difference between groups in the length of fixations in Mechanical AOIs, $U = 57.50$, $Z = -0.84$, $p = .410$, or outside either AOI, $U = 58.5$, $Z = -0.79$, $p = .431$.

Wilcoxon signed ranks tests showed that the Control group had significantly longer fixations within the Social AOIs than the mechanical AOIs, $Z = -3.06$, $p = .002$, and within the Social AOIs than outside either AOI, $Z = -3.18$, $p = .001$. There was no significant difference in the length of fixations in the Mechanical AOI and Outside either AOI for the control group, $Z = -0.42$, $p = .674$. For the ASD group, there was no significant difference between the length of fixations in Social AOIs and Mechanical AOIs, $Z = -0.45$, $p = .656$, between Social AOIs and outside either AOI, $Z = -1.43$, $p = .152$, or between Mechanical AOIs and outside either AOI, $Z = -0.31$, $p = .755$.

The results of these non-parametric tests show the same significant between and within group differences as the parametric ANOVA used in the main analysis. This therefore supports the use of parametric testing for this variable.